Outcrops occur along the west river bank east of Highway 70 on the flanks of Table Mountain, and are capped by the Lovejoy basalt.

5.5.3.3 Lovejoy Basalt

This Miocene extrusive volcanic rock is dense and very hard, but in most places contains conchoidal joint and fracture surfaces. The basalt flow caps ridges in the Oroville area, and commonly is underlain by the Eocene Ione and gold-bearing gravel. Hydraulic mining of these deposits occurred in a number of places between the town of Oroville and Oroville Dam. The basalt originated from an unknown volcanic center near eastern margin of the Sierra Nevadas about 23 million years ago. The basalt flows were unusually fluid and traveled long distances. Lovejoy exposures occur in the Orland Buttes on the west side of the valley and as far south as Vacaville. It has been penetrated by numerous wells in the valley. The basalt is not exposed along streambanks.

5.5.3.4 Laguna Formation

This Pliocene Formation consists of interbedded alluvial gravel, sand, and silt. It is semi-consolidated, reddish-yellow to tan-green, and about 150 feet thick. It has been correlated with the Tehama of the northern Sacramento Valley. The formation was deposited by the ancestral west-flowing Feather, Yuba, Bear, and American rivers. The Laguna is exposed in river banks in a number of places, but can only be seen during low flows in the lower bank. Along the Feather River, Modesto and Riverbank deposits generally overlie the Laguna and compose most of the bank. Laguna deposits are believed to be the resistant outcrops forming the ledge and rapids at Shanghai bend. Presence of the Laguna exposed in the lower bank is the major reason that banks mapped as Modesto and Riverbank formations are so erosion resistant.

5.5.3.5 Turlock Lake Formation

This Pleistocene Formation consists of deeply weathered and dissected arkosic gravels. The unit represents eroded alluvial fans derived primarily from the plutonic rocks of the Sierra Nevada to the east. Exposures occur on the east side of the Feather River meander belt across from the Oroville wildlife area. No river bank exposures have been identified in the area.

5.5.3.6 Red Bluff Formation

This Pleistocene Formation is a distinctive coarse red gravel in a sandy clay matrix believed to range in age from 0.5 to 1.0 million years. The deposit is a thin veneer overlying the Laguna and Turlock Lake formations. It occurs as elevated platforms on both sides of the river, but has not been identified in any river banks.

5.5.3.7 Riverbank Formation

The Pleistocene Riverbank Formation has been divided into the lower (older and topographically higher) and upper members. The Riverbank is believed to range in age between 130,000 and 450,000 years old. Both members form terrace planforms found on both sides of the river and both consist of weathered reddish gravel, sand, and silt. The lower is somewhat more consolidated and erosion resistant. Both units are typically deposited on benches underlain by Laguna, Ione, and older deposits. In places, the Riverbank Formation forms the edge of the Feather River meander belt, but it has not been identified in any eroding banks.

5.5.3.8 Modesto Formation

The Pleistocene Modesto Formation is a younger set of terrace deposits. The Modesto ranges in age from about 12,000 to 42,000 years old. The unit is composed of a lower and upper member. These terrace levels lie topographically above the Holocene river deposits and consists of tan to light gray gravelly silt, sand, and clay. The lower member is distinguished by a clay-rich pedogenic B-horizon. The upper and lower members constrain the meander belt on both sides of the Feather River for most of its valley length. The Modesto is exposed in a number of river banks as far south as the Sutter bypass. In places, the Laguna underlies the Modesto and may be partially responsible for the greater erosion resistance of these banks.

5.5.3.9 Alluvium

Alluvium is a general description of Holocene river deposits that have not been differentiated, and may include floodplain, point bar, channel, and other deposits found in the Feather River meander belt.

5.5.3.10 Stream Channel Deposits

Stream channel deposits occur in active channels of the Feather, Bear, Yuba, and tributary streams and are transported by present-day hydraulic conditions. These deposits contain clay, silt, sand, gravel, cobbles, and boulders in various layers and mixtures that reflect conditions at the time of deposition. Between 1855 and the early 20th century, a large increase in sediment resulting from hydraulic mining, resulted in the lower Feather River becoming covered in a thick deposit of fine clay-rich, light yellow-brown colored “slickens”. The slickens have been buried by more recent floodplain deposits but are evident in eroding banks along most of the river.

5.5.3.11 Dredge Tailings

These dredge tailings are large piles of gravels and cobbles occurring adjacent to the river between Oroville and Gridley. The tailings are a result of gold mining activity. Large floating dredges were employed to process gravel and extract the gold. A large amount of the cobble and gravel windrows in the Oroville Wildlife area was used to construct Oroville Dam.

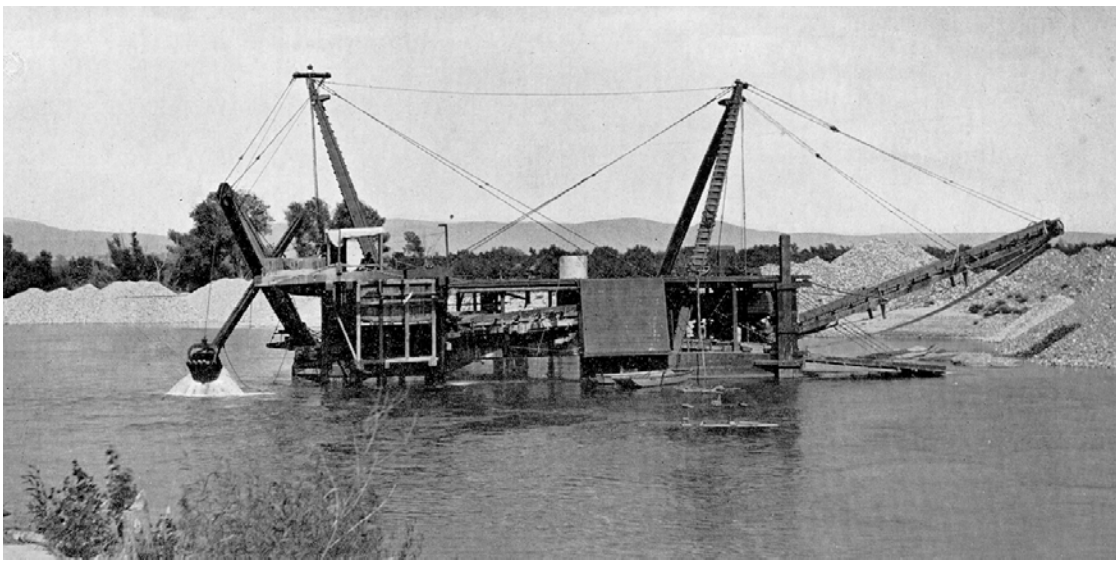

Figure 5.5-6. Floating Dredge Working in the Oroville Area Circa 1900's.

5.5.4 Geologic Structure Downstream of Oroville Dam

The Feather River study area is located in the tectonically active boundary area between the Pacific plate to the west and the North American plate to the east. Most of the approximate four centimeter per year of relative plate motion between these two plates is strike-slip. Faults in the San Andreas system in the California Coast Ranges to the west take up most of this motion. A small part of the overall motion is convergent (compressional), resulting in uplift of the California Coast Ranges, thrust faulting along the western edge of the Sacramento Valley, and folds and faults in the Sacramento Valley proper. One result of the compression is the formation of the Great Valley synclinal trough. The syncline extends from Redding to Bakersfield and is filled with sediments in places over 40,000 feet thick.

The thrust faulting on the west side of the valley is concentrated along a series of segmented, “blind” thrusts collectively called the Great Valley fault (WLA 2002). The Great Valley fault lies on the active, compressional boundary between the Coast Ranges on the west, and the Sierra Nevada on the east and is believed to be the source of historic earthquakes in the area. Faults also occur in the Sierran Basement below the valley floor. The most seismically active of these is the Willows fault in the center of the valley.

Within the Sacramento Valley, compressive deformation appears to have progressed northward over the last five million years. Harwood and Helley (1987) identified a number of structural domains, each with a unique age or date of deformation. This is shown in Figure 5.5-7. The Feather River from Yuba City to Verona is in the Sacramento structural domain, with most of the deformation occurring 3.4 to 5 million years ago. The Oroville to Yuba City reach is part of the Chico structural domain with most deformation occurring from 1.0 million to 2.6 million years ago. It should be noted that much of the deformation within a domain occurred during the specified time interval, but this does not preclude more recent activity.

Moderate earthquake activity has been recorded historically in the valley and Sierra Nevada foothills. The major Mesozoic fault zones of the foothills had long been considered inactive. However, a 5.7 Richter magnitude earthquake, centered 7 miles southwest of Oroville Dam, occurred on August 1, 1975.

The Willows fault is the most significant structure in the study area (WLA 2002). It crosses the Feather River in a northwest direction near Nicolaus, as shown in Figure 5.5-8. The fault is not exposed at the surface, but oil exploration data shows offset of over 1,500 feet in Eocene age deposits. The fault is a reverse fault with east side up, and is seismically active.

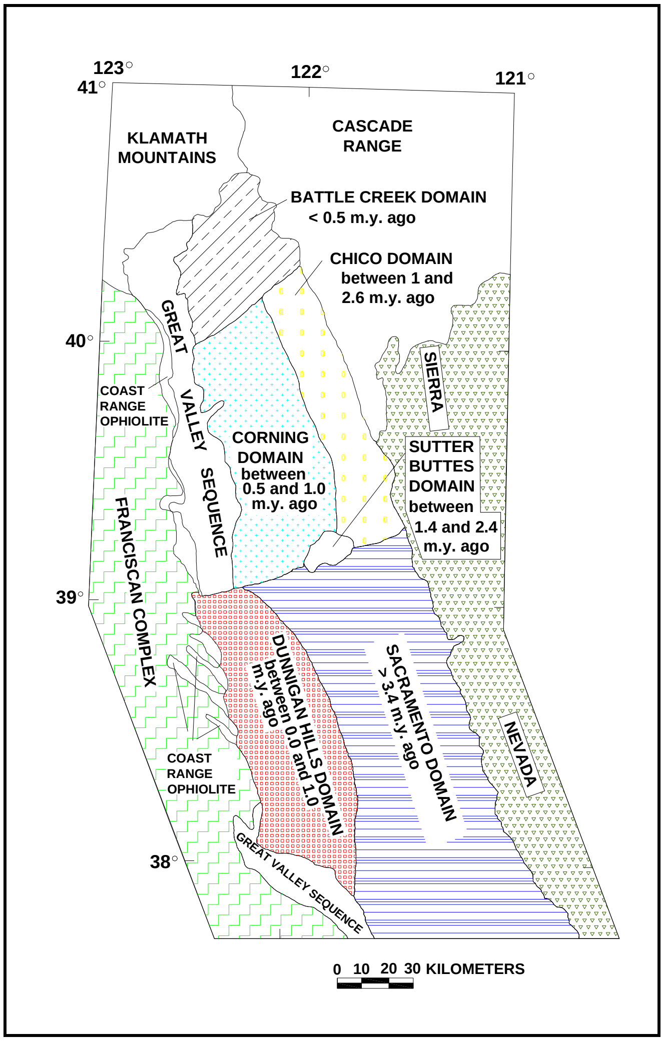

Figure 5.5-7. Structural Domains in the Sacramento Valley.

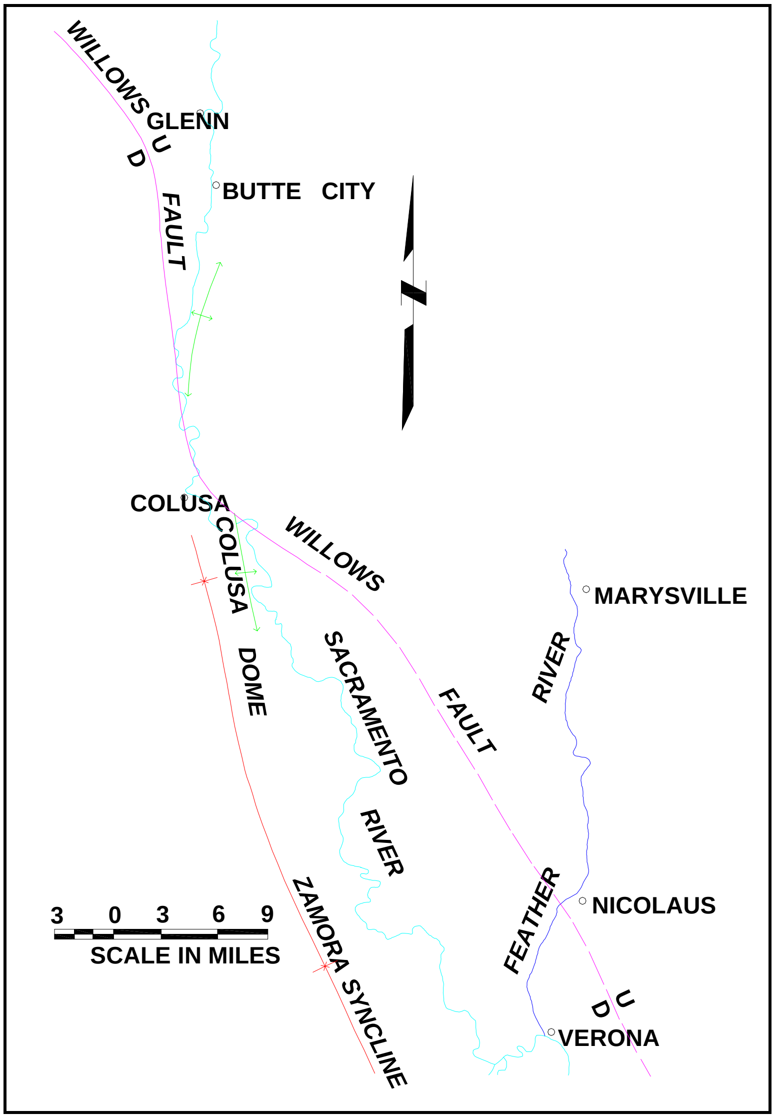

Figure 5.5-8. Intersection of the Willows Fault with the Sacramento and Feather Rivers.

No fold axes have been identified crossing the study area downstream of Oroville, but the Colusa dome and Zamora syncline are mapped toward the center of the Sacramento Valley. Cretaceous and younger sedimentary units share a gentle westward dip common to the east side of the Sacramento Valley basin.

5.5.5 Geologic History

The history of the Feather River system begins near the end of the Cretaceous. Uplift along the western continental margin created the ancestral Feather River basin and Sierra Nevada. Extensive uplift and erosion has occurred since then. Erosion of Jurassic and Cretaceous gold-quartz veins released the gold now found in Tertiary river deposits. The Tertiary Period river channels were in steep and deep river canyons, and were probably fairly similar to the Feather today.

During the mid- to late Eocene, the topography and stream gradients had been reduced, causing aggradation and floodplain formation in the lower reaches. Volcanic activity began by the Oligocene. Rhyolitic tuffs blanketed the gold-bearing gravels under several hundred feet. Streams cut new channels between volcanic eruptions.

Andesitic mudflows were common during the Miocene and Pliocene. These covered the western slope of the Sierras, forcing the rivers to cut new channels once again. Mudflow deposits reached thicknesses of 500 feet in mid-foothill regions (Lindgren 1911, in Wildman 1981), obliterating the existing river system.

Uplift and westward tilting of the Sierra Nevadas as a result of Basin and Range geomorphic province- type extension began in the late Pliocene. Streams began incising through the volcanic cover, eventually reaching present-day positions well below the Eocene auriferous river channels. The Eocene river gravels are now located on ridge tops above the steep V-shaped canyons.

5.5.6 Tectonic Setting

The Oroville Area records the plate tectonic interaction between the Pacific, Gorda, and North American tectonic plates since the Mesozoic. Complex deformation, consisting of mélanges, faults, and folds, combined with volcanic activity, granitic intrusion, uplift, and erosion are the result of this interaction.

The story first begins in the Jurassic when the precursor to the Pacific plate was subducting eastward under the western margin of the North American plate. At the end of the Jurassic era, an island arc collided with the North American plate. Remains of the island arc can be seen today in the Sierra Nevada foothills. Plate subduction then moved westward. Figure 5.5-9 is a cross-section showing the tectonic setting during the late Mesozoic.

The area between the subduction zone and the North American continent is now represented by rocks and deposits of the California Coast Ranges. These include ocean sedimentary and volcanic rocks, metamorphic rocks, ultramafic mantle rocks, and subduction zone mélanges. The Coast Range ophiolite and the Franciscan complex therefore accumulated and was deformed in a trench above a subducting slab.

The Great Valley sequence, consisting of sandstone, mudstone, and conglomerate, were deposited on the continental shelf between the continent and the east-dipping subduction zone.

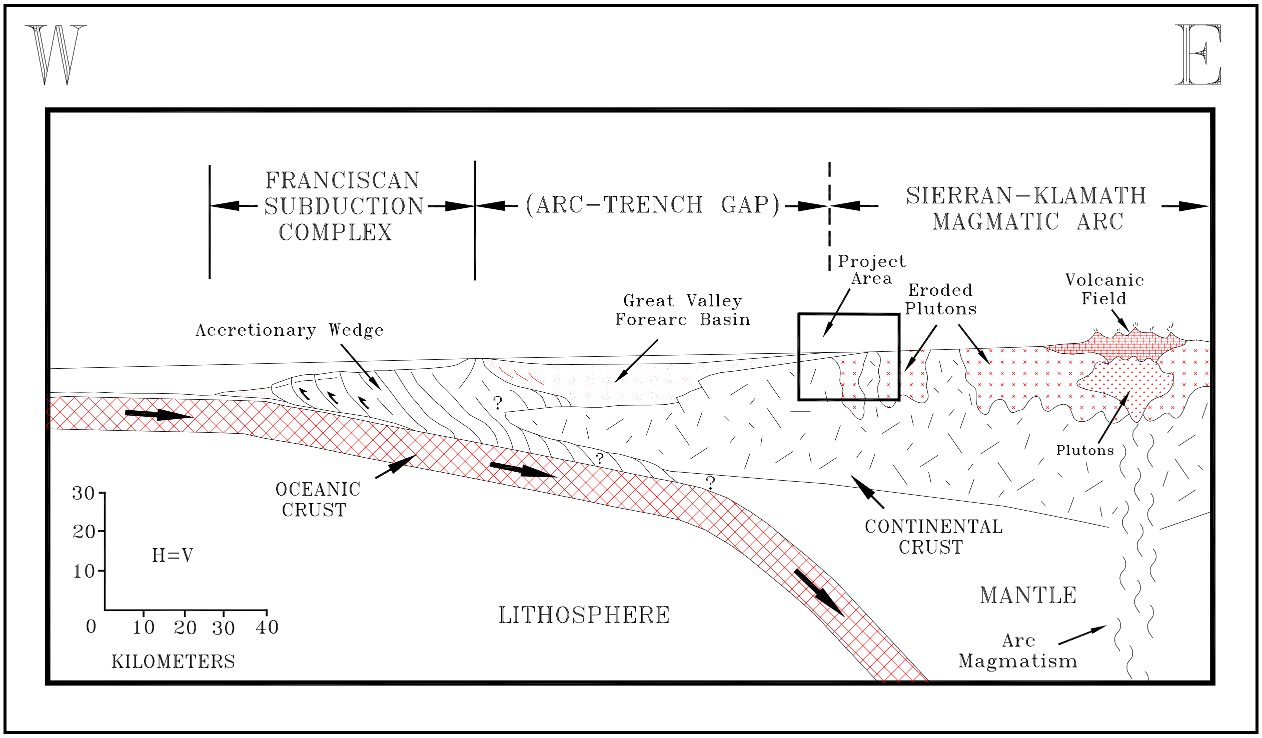

Figure 5.5-9. Schematic Profile of Subduction System Across Northern California during the Late Mesozoic .

The Great Valley sequence has been uplifted, folded and is now exposed along the western boundary of the Sacramento Valley.

The Sierra Nevadas were intruded by batholiths resulting from the eastward subduction. Intrusions vary in age from over 210 million to less than 70 million years, evidence of a long period of plate interaction and subduction.

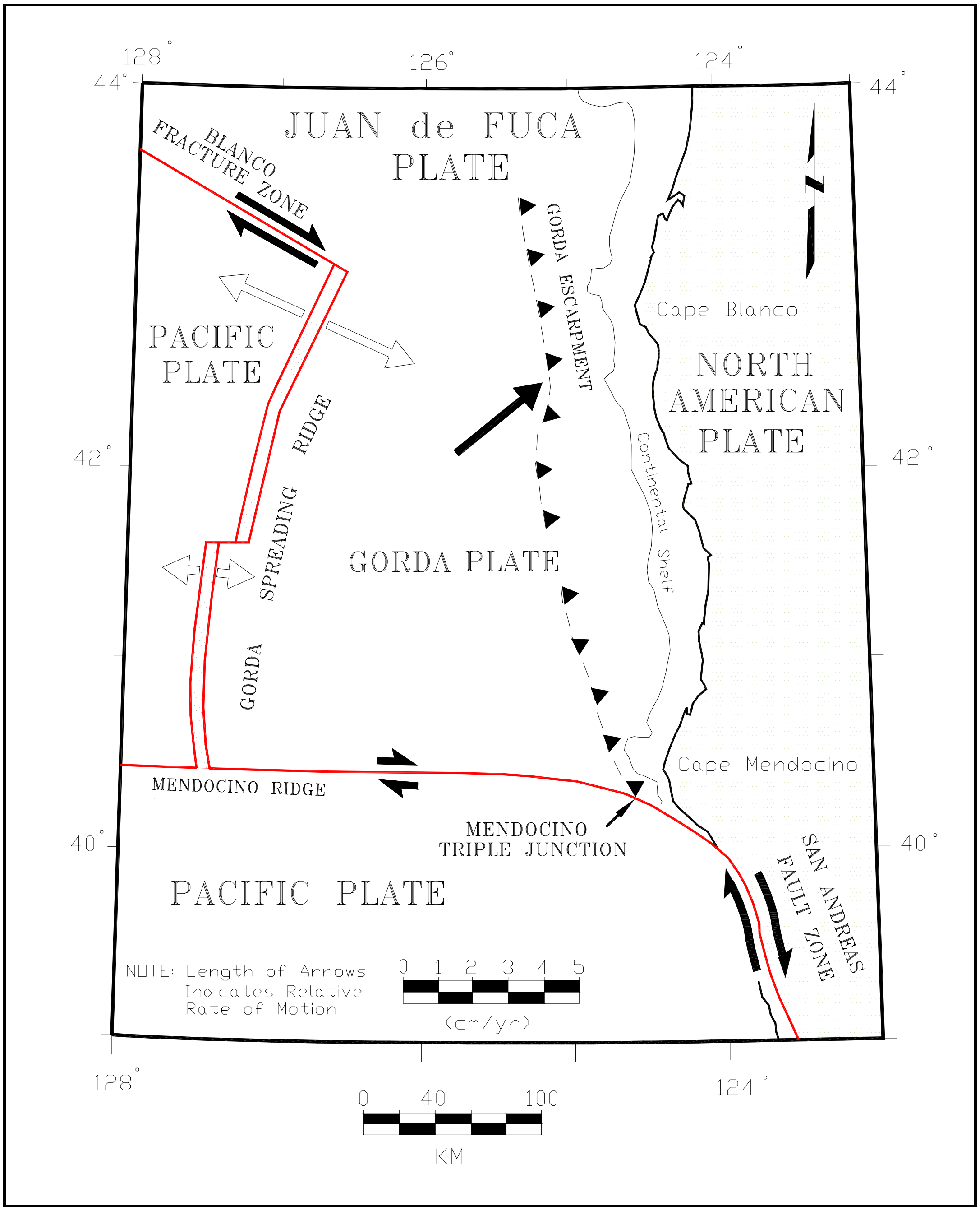

Figure 5.5-10. Mendocino Triple Junction and Plate Boundaries

A change from a convergent plate boundary to a transform fault boundary began about 30 million years ago with the collision of the east Pacific rise spreading center with the trench somewhere near south-central California. This collision formed the Mendocino triple junction, which has migrated northward, and progressively changed the margin from a convergent plate boundary to right lateral strike slip boundary. The trace of the San Andreas fault system has formed since about 6 million years ago, during which time the Mendocino triple junction migrated from a latitude near San Francisco northward to its present location opposite Cape Mendocino in northern California, as shown in Figure 5.5-10. The San Andreas and associated right lateral strike- slip faults now form the transpressional plate boundary in this part of California.

The modern transpressional plate tectonic setting consists of both compression and right lateral strike slip. The slip between the plates is not solely accommodated by the San Andreas, but is distributed across a 745-mile wide zone that spans much of California and Nevada. The Great Valley fault, Willows fault, and the Foothills fault system are all evidence that the study area is seismically active.

The Feather River watershed includes portions of the Cascade Range, Great Valley, and Sierra Nevada geomorphic provinces. Each province has unique geology and topography, reflecting fundamental differences in geologic history. Primary rock types in the watershed are granitic, volcanic, metamorphic, and sedimentary. Rock ages range from Ordovician to Recent, with most being middle and late Mesozoic. The chief structural feature is the Foothills fault system, consisting of parallel faults oriented roughly southeast-northwest.

5.6 SOILS

Soils information for Yuba and Sutter Counties and preliminary information for Butte County was collected from the Natural Resources Conservation Service. The soils distribution is captured on the GIS layers. The soils in this area are found on relatively level land, with the majority of slopes ranging from zero to two percent. The highest slope, with the exception of river banks and road cuts, is five percent. The most common parent material for the soils is river alluvium with some soils derived from sediment, deposited during hydraulic mining of the Sierra Nevadas.

The predominant soil types or textures in the 100 year flood plain are characterized as fine sandy loam, loamy sand, and loam and silt loam. Minor soil types are clay, clay loam, sandy clay loam, sandy loam, silt loam, silty clay, sand and gravel, and river wash. Many of the soils are further divided by occurrence of flooding, such as occasionally flooded to frequently flooded.

The soils range from shallow to very deep, with most moderately deep to very deep. The soils in the flood plain are conducive to agriculture and many areas of riparian floodplain and fluvial terraces have been converted to irrigated crops and orchards.

Several of the named soil series are common to both Yuba and Sutter counties. The Columbia, Hollipath, Conejo, and Shanghai soils cover the most area in the Yuba and Sutter county area of the Feather River flood plain. The Feather silt loam in Yuba County is believed to be the same as the Shanghai silt loam in Sutter County and is described as such.

Feather River floodplain soils are mapped as Shanghai-Nueva-Columbia in Sutter County and Columbia-Tujunga or Ramada-Valdez in Yuba County. Low terrace soils, probably on Modesto Formation, are mapped as Conejo-Tisdale or San Joaquin-Cometa in Sutter but are not mapped in Yuba County. The Wyman-Ryder and Yokohl-Kimball develop on alluvial fans in Yuba County. Soils developing in basins and on basin rims include the Oswald-Gridley-Subaco and the Clear Lake-Capay in Sutter and the Landlow-Yokohl in Yuba counties. Older terraces and alluvial fans are in the San Joaquin-Ramona or Redding-Corning association in Yuba County.

Soil development in the Feather River flood plain is related in part to the parent material of the nearby geologic formations. USGS Bulletin 1590 (1989) addresses the stratigraphy of the area and the relation of the geologic formations to the development of alluvium and soil profiles. The Feather River passes through or is adjacent to several Tertiary and Quaternary geologic formations: The Modesto Formation, the Riverbank Formation, the Laguna Formation, as well as dacitic lahars and their related sediments, and the dredge tailings from the mining of the Sierra Nevadas. The following is a summary of the geologic units and their associated soils. All data is from USGS (1989)

The Modesto Formation is divided into upper and lower members. The upper member is not extensive in the Feather River area. Some of the upper member deposits were dredged for gold. The upper member is found near the crossing of Hwy 70 at Honcut Creek. Where found, the upper member is composed of fine silt and silty fine sand. Soils formed on the upper member are designated as Wyman series soils and are brown loam or silt loam with strong brown colors, and strong blocky structure.

The lower member of the Modesto Formation consists of alluvial and possible lacustrine sediments of late Pleistocene age deposited by the Feather and Yuba rivers, and other small streams and creeks draining the low foothills. The lower member is extensive in the Feather River area. The sediments of the lower member are stratified sand and silt deposited as overbank sediments by the Feather River and distributary channels. Soils formed on the lower member of the Modesto are diverse, leading to difficulty in mapping.

Soils formed on distributary channels of the lower member are designated as Ryer coarse variants, and are weakly developed on the coarse, somewhat excessively drained materials. The finer soils of the Ryer series are moderately to strongly developed with horizons ranging from about 10 to 13 percent clay.

The middle Pleistocene Riverbank Formation is also subdivided into an upper and lower members. The Riverbank consists of mixed, well-sorted sand and silt that is similar in physical appearance to alluvium found in older units. The silt and silty sand are compact, finely laminated and cross-laminated. The upper member was deposited over a wide area as the thin veneer of silt and sand, with some coarser sandy and gravelly deposits. A silica-cemented duripan developed between the upper and lower members because of the restricted water movement into the underlying silt stratum. The surface extent of the lower member is not as great as the upper member. The soils formed on the surface of the Riverbank are locally referred to as “red clays”, and are deeper, redder, and more strongly developed than those found on Holocene alluvium and Modesto Formation. The Yokohl, San Joaquin, Kimball, Kimball deep variants, and Ramona series soils are all associated with the Riverbank Formation. The Riverbank Formation unconformably overlies the Laguna Formation.

The Plio-Pleistocene Laguna Formation consists of a tuff and two distinct alluvial units of different ages. The alluvial units make up the upper and lower members of the formation. The Nomlaki Tuff member occurs near the base of the lower member. The upper member consists of fluvially deposited gravel, sand, silt of mixed lithology and mineralogy. Beds of sand and silt are more common than gravel beds in the upper member. There are many sandy and silty beds that have a tuffaceous appearance, and there are local abundant volcanic clasts in the gravel beds. The lower member of the Laguna lies unconformably on top of Jurassic bedrock and the dacite unit. The lower member consists of fluvially deposited gravel, sand, and silt of mixed lithology and mineralogy. The great age and complex depositional and erosional history of the Laguna Formation produced a large array of soils on various parts of the formation. The soils found on little eroded parts of the uppermost gravel bed of the upper member are of the Redding or Red Bluff series, a yellowish-red very gravelly loam and a red gravelly clay. Around the Oroville airport and the Themalito Afterbay area the soils are Corning series. Other soils of the upper Laguna Formation have been mapped as the Cometa series, the Agate variant, the Altamont, and the Burris series. The lower member of the Laguna has a variety of associated soils, commonly strong variants of the Redding and Corning series.

Properties of the soils found in the study area are shown In Table 5.6-1.

Table 5.6-1. Soil Properties.

Soil Series	Surface Texture	Depth	Drainage	Acreage in Study Area	Slope	Class	genesis	crop
Shanghai	silt loam	very deep	poor	22990	level			
Nueva	loam/clay loam	very deep	poor	19970	level			
Columbia	Silt loam	very deep	poor	14380			floodplain alluvium	
Conejo	loam	deep-very deep	well drained	37860	level-nearly level		alluvial terrace-Laguna	
Tisdale	clay loam	moderate deep		7405				orchards crops
San Joaquin	Sandy loam/clay	moderate deep	well	15285	level-nearly level		alluvium	rice
Cometa	loam/clay loam	very deep		11785				rice, wheat, barley
Oswald	clay	moderate deep	poor	24095	Level-nearly level		Laguna	
Gridley	clay loam		moderate	9905				
Subaco	clay		poor	11585				rice, prunes
Clear Lake	clay	deep, very deep	poor	44035	level, nearly level		alluvial	
Capay	silty clay		moderate	47665				rice, tomatoes
Columbia	medium	very deep	moderate well to poor	7800			floodplain alluvium	orchards crops
Tujunga	loamy sands	very deep	excessive				recent flood deposits	orchards crops
Ramada	sandy to silty	deep	Well-moderate well				slickens deposits	orchards
Valdez			moderate to well				recent flood plain-slickens	orchards
Wyman - Ryder	medium to fine clay loam	deep	well				younger alluvial fans	

Soil Series	Surface Texture	Depth	Drainage	Acreage in Study Area	Slope	Class	genesis	crop
Yokohl - Kimball	loams with claypan	shallow to moderate deep	moderate well				older alluvial fans, igneous-metamorphic	rice and pasture
Landlow - Yokohl	clayey	shallow to deep	poor				alluvial basins	rice, pasture
San Joaquin - Ramona	loam, clay subsoil	shallow to deep	poor to moderate				older alluvial fans, granitic	
Redding - Corning	gravelly loam with clay pan	shallow					old fans and terraces with gravel	dryland range

Source: Natural Resources Conservation Service

5.7 FLUVIAL GEOMORPHOLOGY

Fluvial geomorphology is the science that studies the nature, origin, and development of a river and its relationship to geology, underlying structures, erosion and deposition, and the history of geologic changes as recorded by the river and related surface features. Surface features include point bars, islands, multiple channels, floodplains, terraces, natural levees, and others.

The Feather River enters the Sacramento Valley from the Sierra Nevada about 70 miles south of the valley head. The river then turns sharply to the southeast and follows the valley margin. Terrace deposits of the Modesto and Riverbank formations separate the river from the Butte Basin. The Yuba and Bear rivers join the river nearly at right angles before the Feather flows into the Sacramento River at Verona.

Tectonic activity may be partially responsible for the location of the river. Folding and faulting, generally trending NW-SE, are caused by compression along the Pacific and North American plate boundary. The Willows fault, buried under sediment in the Sacramento Valley, is responsible for uplift on the valley's east side. The geologically recent uplift may have trapped the Feather River along the edge of the valley.

The Pliocene Laguna Formation is exposed along the river in a number of places. Near Oroville and below the Highway 70 bridge, Laguna occurs in the lower bank and in the bed. Laguna also occurs in the lower bank where Modesto and Riverbank terrace deposits occur in the upper bank. Shanghai bend, downstream of Marysville on the Feather River, appears to be incised into Laguna Formation sediments.

Terrace deposits of the Quaternary Riverbank and Modesto formations constrain both sides of the Feather River meander belt in places. Modesto terrace deposits are the most common. They define the limits of river meandering during the Holocene (last 10,000 years). The historic river meander belt is over two miles wide near Oroville, but narrows gradually to about a mile towards Marysville. Below Marysville and the confluence of the Yuba, the meander belt again broadens somewhat. The meander belt nearly doubles in width the last five miles before entering the Sutter bypass and the Sutter basin.

5.7.1 River Classification

The modern river reflects the effects of current climate, lithology, depositional, and erosional history, and the mediating effects of broad vegetation zones. Because these factors generally change slowly, they establish the basic template for the characteristics of the fluvial system. The interaction of climate, geology, and topographic relief drive the energy gradients within a fluvial system and determine subsequent erosional and depositional processes. The river is also influenced by human induced factors such as increased sediment yield from the watershed, dams, hydraulic mining, diversions. The fundamental components of river morphology are its dimension, pattern and profile (Rosgen 1996).

The objective of classifying streams on the basis of channel morphology is to set categories of discrete stream types so that consistent, reproducible descriptions and assessments of condition and potential can be developed. Such assessments can then be extrapolated to similar stream reaches in other areas. Specific objectives of stream classifications include predicting a river's behavior from its appearance, developing specific hydraulic and sediment relationships for stream types, and providing a consistent frame of reference for communicating stream morphology.

5.7.1.1 Rosgen Stream Typing

The Rosgen stream classification system was chosen for this project because of its common use for classifying western streams and its recognition among the different scientific disciplines working on this project.

Rosgen classification of natural rivers places a heavy emphasis upon dimensional properties to define eight primary stream types. A hierarchical decision tree distinguishes types based on the number of channel threads, and the dimensional properties of entrenchment ratio, width-depth ratio, and sinuosity. Entrenchment ratio, sinuosity, and width-depth ratio have decision rule ranges that acknowledge the continuum of stream variability. Sediment size and channel slope are used to classify the eight types into subcategories (Goodwin 1999)

5.7.1.1.1 Rosgen Level 1 Stream Typing

Information for Level 1 typing was acquired from USGS topographic maps, aerial photography, and topographic mapping and cross-sections prepared for the Army Corps of Engineer's Comprehensive Study. Cross-sections were examined and entrenchment ratios calculated every mile. The shape of the channel was determined from the cross-section, and the sinuosity was calculated using successive cross-sections. The Rosgen Level 1 typing is shown in Appendix A.

The entrenchment ratio is calculated using the formula:

$$\text{Entrenchment Ratio} = \frac{\text{flood-prone area width}}{\text{bankfull surface width}}$$

Analyses of channel length and sinuosity were done using aerial photographs from 1999. The sinuosity was calculated for river reaches with similar entrenchment ratios using the formula:

$$\text{Sinuosity} = \frac{\text{river centerline length}}{\text{down valley length}}$$

The Level I analysis indicates that the Feather River may be classified into two stream types. River miles 67 to 64 were designated as stream type "C". From river mile 64 to RM 15, the Level I designation was stream type "F". From RM 15 to the RM 0 at Verona, the stream type became type C again because of the artificial levee system.

Stream type "C" is described as low gradient, meandering, point bar, riffle/pool, alluvial channel with a broad, well defined flood plain. The C stream types are located in narrow to wide valleys constructed from alluvial deposition with well developed floodplains. They are generally relatively sinuous. Channel slopes are 2 percent or less, width/depth ratios are generally greater than 12, and sinuosities exceed 1.4 (Rosgen 1996).

Stream type "F" is described as an entrenched meandering riffle/pool channel with low gradient and a large width/depth ratio. The F stream types are incised in valleys of relatively low relief containing erodible materials. The F stream systems are characterized by moderated riffle/pool sequences (Rosgen 1996).

5.7.1.1.2 Rosgen Level 2 Stream Typing

The Level II classification employs more finely resolved criteria such as sediment supply, stream sensitivity to disturbance, recovery potential, channel response to flow regime changes, and fish habitat potential. Rosgen Level II stream typing adds the characteristics of dominant channel materials and water surface slope to the criteria of the Level I analysis.

The water surface slope between each pair of cross-sections was calculated by dividing the elevation difference of the water surface taken from the cross-section data by the centerline length. The channel material was evaluated by several trained geologists using visual observation. There were only a few locations where the channel bottom was not observable because of water depth and turbidity. Substrate classifications are 1-bedrock, 2-boulders, 3-cobble, 4-gravel, 5-sand, and 6-silt/clay. The Rosgen Level II classifications are shown in Appendix A.

5.7.1.2 Feather River Geomorphic Reaches

A river may be divided into geomorphic reaches, that is, sections of a river that share similar characteristics, but are different from the reach above and below. River reaches can be classified according to a number of different classification schemes that include such river characteristics as channel shape, gradient, planform, bed material, depth/width ratio, and others.

The Feather River was divided into 11 geomorphic reaches based on a variety of geologic and channel configuration characteristics. The first four reaches are the same as used by Water Engineering and Technology (WET 1990). Reaches FR-5 to FR-11 were determined by aerial photos, topographic maps, cross-sections, and field inspection. The reaches are shown in Table 5.7-1 below.

5.7.1.2.1 River Reach FR-1

Reach FR-1 extends from the mouth of the Feather River where it joins the Sacramento River near Verona upstream to where the Feather enters the Sutter Bypass. The Willows fault crosses the channel at the upstream end of the reach. The channel is entirely in the bypass in this reach, resulting in backwater effects during major floods. The channel is straight and narrow, with tall banks for the most part. River banks consist of floodplain deposits of sand and silt overlying slickens. The south bank is leveed. The slickens are generally not visible during high summer flows, but provide bank stability over most of the reach. It appears that the banks on both sides are stable, resulting from the cohesive clay slickens that are exposed in the lower banks.

Table 5.7-1. Geomorphic Reaches of the Feather River .

Reach	River Miles	Bed Composition	Bank Composition	Slope	Stream Type	Sinuosity
FR-1	0.0 - 7.0	Sand	Sand and Silt over Slickens		Alluvial Stable	low
FR-2	7.0 - 12.5	Sand	Sand and Silt over Slickens		Alluvial Meandering	low
FR-3	12.5 - 17.0	Sand	Sand and Silt over Slickens		Alluvial Geologic Control	low
FR-4	17.0 - 28.0	Sand	Sand and Silt over Slickens		Alluvial Geologic Control	moderate
FR-5	28.0 - 33.5	Sand	Sand and Silt over Slickens		Alluvial Stable	low
FR-6	33.5 - 35.5	Sand and Gravel	Sand and Silt over Slickens		Alluvial Erodible	high
FR-7	35.5 - 39.5	Sand and Gravel	Sand and Silt over Slickens		Alluvial Stable	low
FR-8	39.5 - 46.5	Gravel	Sand and Silt over Slickens		Alluvial Erodible	moderate
FR-9	46.5 - 53.5	Cobble and Gravel	Cobble and Gravel		Alluvial Stable	low
FR-10	53.5 - 64.0	Cobble and Gravel	Cobble and Gravel		Dredger Tailings	NA
FR-11	64.0 - 68.0	Bedrock	Cobble and Bedrock		Bedrock	NA

The bed consists of moving bars of sand. These move and shift even during summer irrigation flows. The bars are for the most part submerged during the summer, but are visible in aerial photos. During low fall and spring flows, some bars are above the water surface. These bars are the most prevalent in the first four river miles.

5.7.1.2.2 River Reach FR-2

FR-2 begins where the river leaves the Sutter Bypass at RM 7 and goes upstream to RM 12.5. The reach is characterized by the presence of alternate bars on the channel margins and large sand waves within the channel. Islands occur in the channel, some with riparian vegetation, suggesting an element of permanence. The sand waves migrate slowly with time. The river is on the average nearly twice as wide as it is in Reach F1. The banks vary in composition. Typically one side of the river has a bank consisting of floodplain silt and sand overlying slickens. The opposite bank typically consists of active point bar deposits of sand with some silt.

This type of paired bank deposit indicates that some limited bank erosion and meandering has occurred since deposition of the slickens. This explains the presence of a wider channel, lateral sand bars, multiple channels, and mid-channel islands.

5.7.1.2.3 River Reach FR-3

Reach FR-3 is from RM 12.5 to 17. The reach is mostly wide and straight. The bed consists of sand, with sand bars moving and shifting with time. Point bar development is typical on the inside of the wide, sweeping, low curvature bends.

Bank composition is about evenly split between alluvial, with silt and sand evident in the banks, and banks with slickens in the lower layer and an erodible upper layer of gray floodplain silt and sand. The slickens are cohesive, erosion resistant, and promote channel stability.

5.7.1.2.4 River Reach FR-4

Reach FR-4 extends from RM 17 upstream to RM 28, where the Yuba River joins the Feather. Several large meanders occur near the bottom of the reach. Erosion resistant Modesto Formation is exposed in some places. Most banks consist of floodplain deposits overlying slickens. The bed consists mostly of sand.

Shanghai Bend is near RM 25. The bend is a rapid, with a near-vertical drop of several feet in places. The rapid is underlain by an erosion resistant unit that appears to be Laguna Formation, with Modesto Formation on top. Jet boats can navigate the bend at summer flows, but generally not at low spring and fall flows.

The Modesto Formation is exposed in the eastside bank upstream of and in the bend. Modesto also occurs in a few other places in the reach, adding to bank stability. In a few places, and in particular at Shanghai bend, gravel and cobbles appear on bars. These are a result of bank erosion and bank protection, and are not indicative of the transport capacity of the river.

5.7.1.2.5 River Reach FR-5

Reach FR-5 begins at the mouth of the Yuba River at RM 28 and extends upstream to RM 33.5. This reach is fairly straight, shows minimal bank instability and meandering, and has a low sinuosity. The floodplain is confined by older terrace deposits and levees to a width that is typically less than one mile across. The river is a sand bed stream in this reach, with banks consisting of floodplain deposits overlying slickens. There are minimal point bars or other depositional features, and no multiple channels in this reach. In several places, older Modesto terrace deposits are exposed along the banks, providing additional stability. This reach is in the backwater area of the Yuba River, which enters the Feather at the lower end of the reach.

5.7.1.2.6 River Reach FR-6

Reach FR-6 is short and unstable, extending from RM 33.5 to 35.5. This reach is unusual with very high sinuosity, active bank erosion, and the formation of point bars. The point bars consist of mostly sand and minor gravel. The bars are not armored. Meander cutoffs have occurred here in the past and will likely occur here in the near future.

The upper end of Reach FR-6 marks the transition between a sand-bed and a gravel-bed stream. The bed is mostly sand but also contains pebbles and some gravel. The banks are mostly sand and silt deposited on the presently active floodplain. The sand to fine gravel bed and bank composition is also probably responsible for the instability of this reach.

5.7.1.2.7 River Reach FR-7

Reach FR-7 is from RM 35.5 to 39.5. This reach has low sinuosity, and minimal point bar development. The channel is narrower than Reach FR-6. It is incised into the flood plain, with tall vertical banks. Only minor depositional features, mostly sand bars, are found in the channel. The bed composition is gravel. Banks are composed of slickens overlain by floodplain silt and sand, although in some places the slickens do not appear to be present.

5.7.1.2.8 River Reach FR-8

Reach FR-8 is from RM 39.5 to 46.5. FR-8 is a meandering reach, with a narrow meander belt that is characterized by evidence of meandering on the floodplain. This includes old meander scars, oxbow lakes, and active bank erosion. A number of actively eroding banks occur in this reach. Bank recession of over 500 feet in the last 35 years is common. Armored gravel point bars develop in most of the river bends. The bed is mostly gravel.

5.7.1.2.9 River Reach FR-9

Reach FR-9, extending from RM 46.5 to 53.5, has the first occurrence of cobbles as part of the bed material. This reach is also sinuous, and is characterized by multiple channels, mid-channel islands, point bars, and a gravel-cobble bed. The reach is not meandering, but localized bank erosion does occur.

The banks are typically of floodplain silt. In some places (RM47.8R, RM50.5R, and RM53.5L), geologic control in the form of the Modesto Formation is encountered. Yellow slickens are observed in some bank outcrops and also provide a degree of bank stability. Bank protection has been placed on the right bank near the Gridley Bridge.

The floodplain of Reach FR-9 is characterized by distributary overflow channels, most of which have been filled in by land leveling and farming activity. It is not known if the channels are a result of deposition of hydraulic mining debris, or a relict feature from pre-mining days.

5.7.1.2.10 River Reach FR-10

Reach FR-10 extends from RM 53.5 to 64.4 and is contiguous with the Oroville wildlife area. FR-10 is separated into two sub-reaches based on streamflow. FR-10A is part of the low flow reach that ends at the Thermalito Afterbay outfall. FR-10B extends from the outfall to the downstream end of the reach. FR-10B has the combined flow releases from Thermalito Afterbay and the Low Flow Channel. Both sub-reaches are characterized by coarse dredge tailings composing both the bed and banks. Riffles, point bars, mid-channel islands, and multiple channels are common, but most of these depositional features are armored by cobbles and boulders. These features are believed to be relict and static, or left over from pre-Oroville Dam hydraulic conditions.

Levees severely constrict the floodplain along most of FR-10A. Overflow weirs into the Oroville wildlife area occur in at least four places. Much of FR-10A has been mined for gravel, resulting in many pits, multiple channel areas, and resultant channel complexity.

5.7.1.2.11 River Reach FR-11

Reach FR-11, from RM 64.4 to 68, is characterized by geologic control. The river is a bedrock stream. It is incised into Upper Jurassic metavolcanic rocks from the diversion dam to the Highway 70 bridge. From there to the downstream end of the reach, it is incised into the Laguna Formation. Both the bed and banks are stable, although coarse cobbly hydraulic mine tailings comprise the upper bank in some places. There is no evidence of any channel shifting.

Older geologic deposits form tall cliffs adjacent to the channel on the right bank. Similar to FR-10, there are relict mid-channel islands and point bars that are no longer active depositional features. The bed material is bedrock that is covered in most places by a veneer of cobbles and boulders up to 10 feet thick. Salmon spawning gravel enhancement projects were done here in the 1980s.

5.7.2 Habitat Typing and Physical Characteristics

Mesohabitat mapping was performed from the Fish Diversion Dam below Lake Oroville to Verona. The field measurements included recording the location of riffles, runs, glides, pools, the substrate description, and the instream fish cover on the 2001 1:7200 aerial photo atlas. Depths of pools were also recorded in the field and then checked against the 1997 USACE 2 - foot contours. The widths were measured from ArcView shapefiles containing the mesohabitat line work. Habitat classifications were based on the California Salmonid Stream Habitat Restoration Manual (DFG 1997). Riffles are defined as shallow reaches with swiftly flowing, turbulent water. A glide is a wide, uniform channel bottom with flow of low to moderate velocities, lacking pronounced turbulence. A run is a swiftly flowing reach with little surface agitation and no major flow obstructions. Pools are areas of increased depth and reduced current. A classification of ”backwater” was added to account for the areas of little or no current away from the main channel. The cover codes were also taken from the manual and are:

- 0=No shelter.
- 1=One to five boulders or a bare undercut bank or bedrock ledge or one piece large woody debris.
- 2=one or two pieces large woody debris with small woody debris, six or more boulders per 50 feet, undercut bank with root mass, a root wad, branches in or near the stream, limited submerged vegetation, or a bubble curtain.
- 3= at least two of the following; large woody debris, boulders, root wads; Three pieces large woody debris with small woody debris; three boulders with large woody debris/small woody debris; bubble curtain with large woody debris or boulders; undercut bank >12 inches with rood mass or large woody debris; extensive submerged vegetation.

Figure 5.7-1 is an example river atlas sheet showing a typical stretch of the river. Shown on the figure are outlines of the mesohabitat classification and the reach number. Appendix C is the mesohabitat data table for all reachs.

Between Oroville and Yuba City there are 61,333,019 ft^2 of habitat. The majority of the habitat is composed of glides (47 percent) and pools (36 percent). Riffles compose seven percent, backwaters and runs compose five percent each, and boulder runs compose less than one percent of the total habitat. The data is also in the DWR Arcview- GIS coverage of the Project. Table 5.7-2 presents the relevant statistics generated from the mapping.

Table 5.7-2 Mesohabitat from Oroville to Yuba City

Habitat Type	Area (ft^2)
Backwater	3,209,675
Boulder Run	30057
Glide	28,748,554
Pool	22,371,508
Riffle	4,089,226
Run	2,883,999
Total	61,333,019

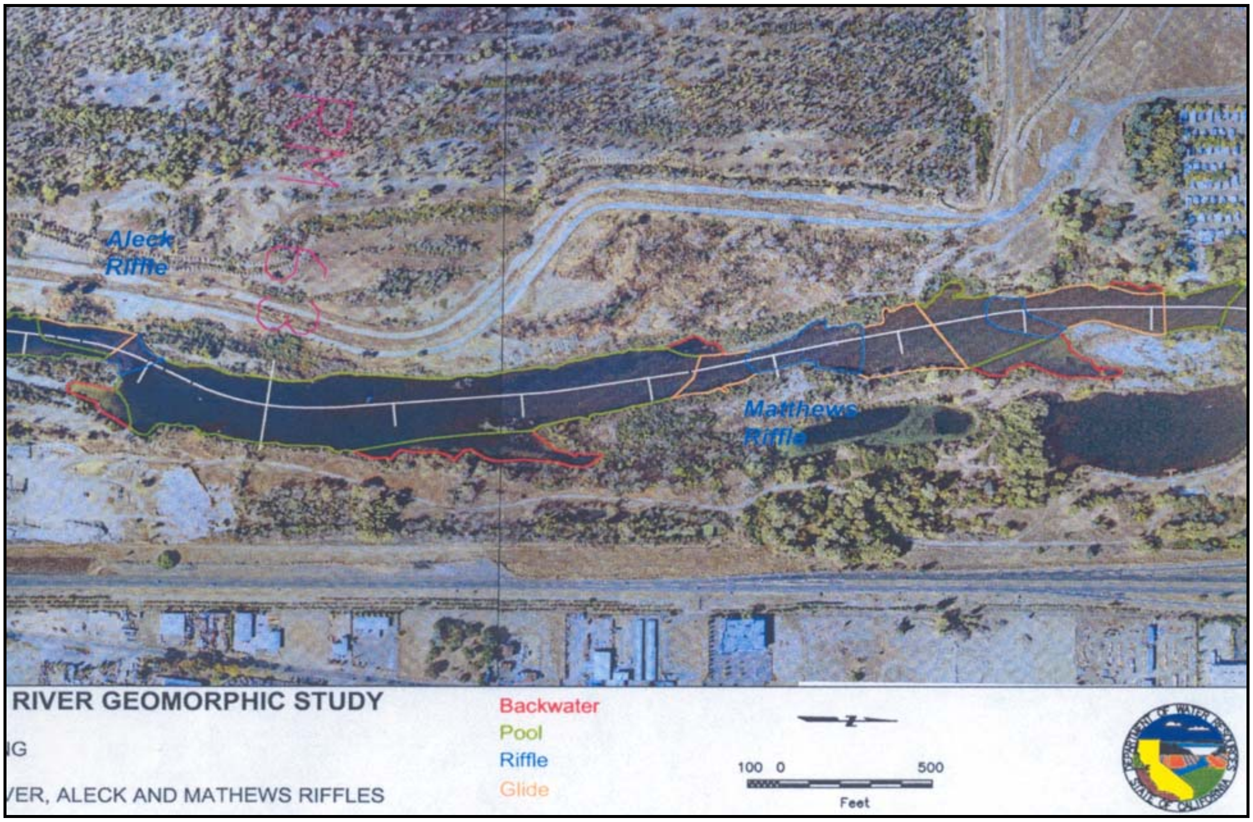

Figure 5.7-1. Feather River Aleck and Mathews Riffles - Mesohabitat Typing.

5.7.2.1 Meander Characteristics

A mature alluvial stream traverses the Feather River floodplain, eroding the outside of meander bends and depositing sediment on point bars on the inside. During floods, silt and sand are deposited across the floodplain.

The meander belt is generally defined as the area within which a meandering river shifts its channel from time to time. It is delineated by drawing lines tangentially to the extreme limits of all fully developed meanders. The historic meander belt is defined as the area enclosed by all Holocene (last 10,000 years) meander deposits. The 100-year meander belt is also commonly defined because of the general availability of surveys, maps, and photos for that time period, allowing for accurate delineation of the boundaries.

The meander belt consists of Recent alluvium (Qa) and stream channel deposits (Qsc). The alluvium is older, but both consist of river deposits, including floodplain deposits, point bar deposits, channel fill, oxbow lake deposits, tributary delta deposits, and others. The deposits range in size from clay, silt, and sand to gravel, cobbles, and boulders. On the Feather River, coarse deposits predominate near Oroville and the fine deposits predominate from Gridley and downstream. The historic meander belt is shown on the geologic map in Figures 5.5-3, 5.5-4, and 5.5-5. It is the area shown as Qa. The 100-year meander belt units have been processed and are part of the Oroville Facilities Relicensing GIS database. The Feather River is constrained to a relatively narrow meander belt by erosion resistant terrace deposits of the Modesto and Riverbank formations. The meander belt varies from less than one mile to more than three miles wide.

Normally an alluvial river is balanced in terms of erosion and deposition. Bank erosion occurs along the outside bends by high flow velocities impinging on erodible bank deposits. Coarse sediment deposition in the form of lateral accretion occurs at point bars on the inside of the bends. Vertical accretion of fine sediment occurs on flood plains during overbank flooding. A stream is in balance if the deposition and erosion are equal. The river is aggrading if deposition is greater than erosion, and degrading if erosion is greater deposition. In most cases, a river shifts from aggrading to degrading because of changes in river flow and sediment availability. Geologic units exposed along the Feather suggest that the river was degrading during the Holocene era. The evidence includes older terraces found on both sides of the meander belt.

The lower Feather River, prior to 1855, was a meandering stream, believed to be similar to the present Sacramento River between Red Bluff and Colusa (WET1990). Between 1855 and the early 20th century, a large increase in sediment resulting from hydraulic mining, caused aggradation in the lower Feather River. A thick deposit of fine, clay-rich slickens (as much as 20 feet in Marysville) was deposited in the channel and on the floodplain. This was followed by cessation of mining (1895) and the gradual reduction of sediment as the hydraulic mining debris was washed downstream. Dam construction along the Feather River also added to the decrease in sediment derived from the upper Feather watershed. Dams on the Yuba and Bear rivers have had similar effects. This has resulted in degradation of the channel in the lower river. Consequently, the river has eroded vertically through the hydraulic mining debris, leaving the slickens exposed in channel banks.

5.7.2.2 Channel Sinuosity

Sinuosity is defined as the ratio of river length to down-valley length, and is an expression of the size and number of curves. Overall, the study reach has a sinuosity ratio of about 1.2 measured from topographic maps. This is considered low. The reaches between Oroville and Yuba City have an average sinuosity of - 1.46 to 1.27. WET (1990) calculated that the Yuba City to Verona reach has a sinuosity of 1.1.

The combination of historical observations and present day channel sinuosity suggest that the Feather River was probably more sinuous prior to hydraulic mining than today (WET 1990). The present-day sinuosity is not substantially different from those of the 1920s. Because of the entrenchment of the Feather into hydraulic mining debris and the regulated flows that result from meeting the flood control requirements for the Oroville Facilities, it is expected that the sinuosity will not change substantially in the next fifty years or so.

5.7.2.3 Channel Gradient and Longitudinal Profile

Gradient is defined as the ratio of the change in elevation of the water surface over a selected stream length. It can be expressed as feet per mile or as feet per feet. The average gradient between Oroville and Verona is 2 feet per mile. The gradient is not constant. River reaches are divided into riffle/run/glide/pool segments with a large variation in gradient. Gradients for the ten Feather River reaches are shown in Appendix A.

Thalweg profile for the Oroville to Bear River reach of the Feather River is shown in Figure 5.7-2.

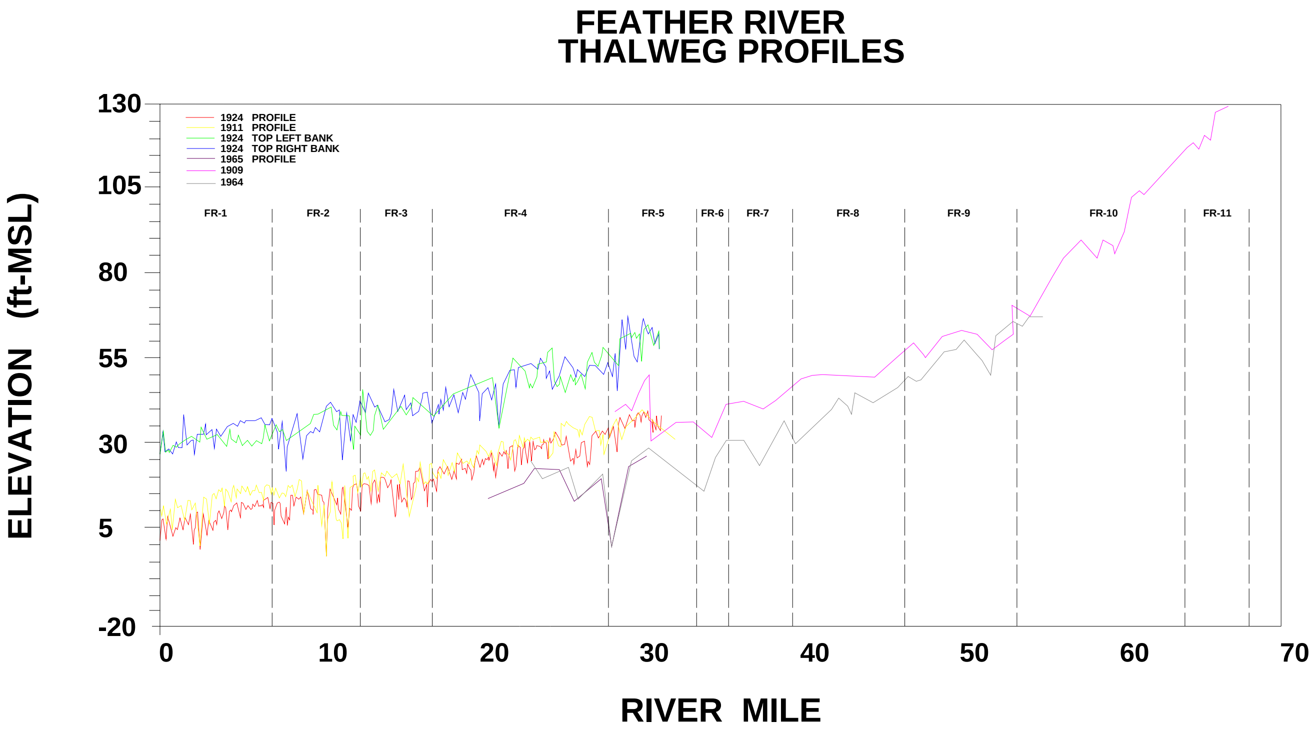

Figure 5.7-2. Thalweg Profiles of the Feather River from 1909 and 1964 Surveys, Reaches FR-1 to FR-8.

5.7.2.4 Channel Depth and Width

The Feather River is still adjusting to changes caused by hydraulic mining and dam construction. The USGS (1972) documented channel changes between 1909 and 1970. The U.S. Corps of Engineers surveyed the Feather River between Oroville and Verona, and published a series of topographic river surveys between 1909 and 1911. Soundings were done at intervals. Details of cross-section analysis performed as part of this study are included in Report 5.2.

The USGS (1972) compared some of these cross-sections in the Oroville to Honcut Creek reach with cross-sections from 1909. These cross-sections are shown in the Task 7 and Task 5 reports. The cross-sections show a large increase in channel area. The cross-section at RM 37.4 shows an 80 percent increase in channel area. The average depth increased by almost five feet. The cross-section at RM 41.9 shows a 250 percent increase in area with little change in depth. Cross-section RM 60.4 shows a 15 percent increase in area and about four feet of thalweg lowering.

In general, the cross-sections show a large increase in cross-sectional area, with an increase in both depth and width. This has also increased channel capacity and the ability to convey flood water without flooding. The increase in depth and width is characteristic of the entire lower Feather River.

The dramatic increase in cross-sectional area since 1907 can be attributed to the influx of large amounts of mining debris, followed by cessation of mining, and subsequent channel widening and incision through the process of bank and bed erosion. Channel widening is also related to the fact that dams in the watershed continue to trap sediment. Without sediment transport, there is no replacement of sediment eroded from the banks and the bed. However, the reduced flood flows attributed to Oroville Dams flood control functions would tend to reduce this effect.

5.7.2.5 Bank Characteristics

Bank erosion varies greatly depending on bank composition. Sand banks are the most erodible, followed by sandy gravel banks. Coarser gravel and cobble banks tend to be more erosion resistant, and erode at relatively slow rates. Banks consisting of clay and silt also erode at slow rates, primarily because of the cohesive nature of clay. The more clay found in the bank, the slower the bank erosion rate. Slickens resulting from hydraulic mining contain abundant clay and subsequently have low bank erosion rates. Banks composed of the Modesto and Riverbank terrace deposits are stable, but can erode when exposed to high velocity streamflow for long periods of time. In places, the Laguna Formation was observed to underlie the terrace deposits. The terrace deposits are considered to be the edge of the meander belt. Bedrock units are considered non-erodible for this study.

5.7.2.6 Bank Composition and Geologic Control

The bank composition was mapped and transferred to a GIS database. The locations of rip-rapped banks were noted simultaneously. The bank composition classifications are as follows:

Alluvial - Alluvial banks were shallow, gently sloping banks exhibiting recent depositional features such as open gravel or sand banks and generally occur on the insides of bends or at riffles.

Bedrock - Bedrock was confined to the Mesozoic bedrock, hard rock, in the upper reaches of the river, diversion dam to Bedrock Park.

Flood Plain - Flood plain deposits are massive to slightly bedded silt sand and clay. The deposits are brown to gray, unconsolidated and occur as steep banks commonly being eroded on the outside of bends.

Laguna – Laguna deposits are yellowish brown to tan, silty clay that are firm and somewhat resistant to erosion. They most often occur as vertical banks at the outside of stable bends and commonly underlie Modesto deposits.

Modesto – Modesto deposits are brown to gray silt to clay that have a well developed soil horizon. They are stable where they overlie Laguna but are erodible where exposed at the waters edge. They commonly occur as steep to vertical banks.

Slickens – Slickens are the hydraulic mining debris deposits and are usually orange-yellow, silt, clay, and sand, and can be massive to bedded. They occur as steep banks on stable stretches of the river and are somewhat resistant to erosion. The river has entrenched into these deposits.

Tailings – Tailings are the dredge tailings from gold mining activities. They form steep banks of cobble and gravel.

Levees and rip-rap are noted where present. The following discussion shows the variation in bank composition in the study area.

From the fish barrier dam to just above the Highway 70 bridge, the bed is metamorphosed volcanic rocks of the upper Jurassic age Logtown Ridge Formation. This is hard and erosion resistant, resulting in a stable bedrock channel. The banks in this area are hydraulic mining debris consisting mostly of cobbles and gravel that have low erodibility. Bank protection has been placed for a short distance below the Highway 70 bridge.

Tall cliffs along the right bank from the Highway 70 bridge to just above the Highway 162 bridge are underlain by Laguna Formation at river level. The top of the cliffs are capped by the Red Bluff Formation. The Laguna Formation is rich in cohesive clay, and is erosion resistant and therefore constitutes geologic control. The left bank consists of mostly coarse cobble and gravel point bar deposits. These deposits have not eroded since construction of Oroville Dam. Levees along this reach constrain the river in areas where geologic control is not present.

Below the Highway 162 bridge, the river opens into the Sacramento Valley. The left bank is composed of erosion resistant Lower Modesto Formation deposits that are also considered to be geologic control. These banks are about 30 feet tall. The right bank on the west side is composed of cobbles and gravel, coarse remnants of hydraulic mining debris, about 20 feet tall. In most areas, the low flow channel is confined by steep banks of this deposit. A levee keeps high flows from entering the Oroville wildlife area, except at overflow weirs. The cobble and gravel deposit is coarse and somewhat erosion resistant. High flow events, such as the flood of January 1997, cause some channel bed and bank erosion. Although the channel has not moved substantially, it has continued to widen and deepen, albeit at a lower rate, since construction of Oroville Dam.

However, between River Miles 62 and 59, gravel mining activity has caused multiple shifts in the channel. Numerous ponds dot the area, and may be partially responsible for channel shifts through pond capture. Future bank erosion and channel shifting in this area is mostly dependent on gravel mining activity. Natural bank erosion may also account for some of the river movement in this part of the river.

Below the Thermalito Afterbay outfall, in the high flow reach, the river continues for the most part in the coarse cobble and gravel deposits to Gridley. The cobble banks presently appear stable, with little evidence of major natural erosion or shifts in the channel.

Lower Modesto Formation is encountered at RM 54.5 on the left bank, about three miles above Gridley and on the right bank at Gridley. The significance of Modesto Formation deposits is that the river has not been beyond that point for at least the last 10,000 years or more. The bank at RM 54.5 is tall and vertical, consists mostly of silt and clay, and appears to be fairly erosion resistant, although some erosion is evident. The Modesto age bank at Gridley has been protected by rock riprap. Although not observed, it is possible that Laguna Formation outcrops along the lower bank below the Modesto.

Older Terrace deposits, mostly Modesto but some Riverbank, constrain the meander belt all the way to the confluence with the Sacramento River. Between Gridley and Yuba City, the meander belt averages only about a mile wide between geologic controls. In a few places in this reach, the river intersects the terrace deposits. In most places, the banks in this reach consist of alluvium, mostly sand and silt overlying clay and silt slickens.

Silt banks continue downstream to the mouth of the Feather. The silt is dark gray and generally constitutes the top of the bank. In some places, sand and gravel constitutes the lower bank. Silt banks are eroding at a fairly rapid rate directly above the confluence with Honcut Creek.

Below Gridley to Yuba City, reddish-yellow “slickens”, or fine hydraulic mining debris, is exposed in the lower banks in places. The slickens were deposited from about 1856 to 1895 as a result of hydraulic mining of gold-bearing gravel. The slickens consists of fine silt with some clay and tends to be erosion resistant.

The cohesive nature of the slickens constitutes geologic control, in that erosion rates are slow. Normal silt banks are interspersed in this reach with the slickens.

Composite banks are common. These consist of a combination of sediment sizes arranged in layers. The most common are banks composed of slickens in the lower bank, and sand and silt in the upper bank. The composition of the lower bank generally controls the bank erosion rate. Another bank combination is sand and gravel underlying silt and sand. This type of bank is a product of the normal meandering stream. The sand and gravel was deposited on a point bar and the overlying silt and sand later accumulated over time on the floodplain. This type of bank tends to be moderately to highly erodible, depending on the amount of sand in the lower bank. The most erodible banks contain sand in the lower layer.

5.7.2.7 Bank Erosion

Bank erosion rates can change because of a number of factors. First, the bank material will change as the river erodes across its meander belt. Second, bend morphology changes with time. Chute cutoffs are the most common of these, resulting in an increase in the radius of curvature. The result is that dramatic shifts in bank erosion loci and rates can occur as a result of these events.

Bank failure processes are similar to that of the lower Sacramento River in that failure modes are highly correlated with bank materials. WET (1991) compiled bank erosion sites for the upper reach of the Feather. Their data show that bank erosion occurs on bends and straight reaches. Rates tend to be higher in bends than straight reaches. Bend morphology is such that velocities are higher along the outside, eroding and undercutting the bank. The smaller the radius of curvature, the sharper the bend, and the more erosion occurs. The low sinuosity of the Feather, however, means that there are far more straight banks than curved. Data measured during this study are presented in the Task 5 report.

Bank erosion is affected by bank moisture. Dry banks erode at a slower rate, all other factors being equal. Wet banks lose soil cohesion, and the water adds weight. Receding flows after bank full discharge tend to be the most erodible because banks are saturated, positive seepage pressures causing piping and liquefaction, and lack of support and buoyancy from receding flows.

Bank erosion varies greatly depending on bank composition. Sand banks are the most erodible, followed by sandy gravel banks. Coarser gravel and cobble banks tend to be more erosion resistant, and erode at relatively slow rates. Banks consisting of clay and silt also erode at slow rates, primarily because of the cohesive nature of clay. The more clay found in the bank, the slower the bank erosion rate. The slickens resulting from hydraulic mining contain abundant clay and subsequently have slow bank erosion rates. Banks composed of the Modesto and Riverbank terrace deposits are stable, but can erode when exposed to high velocity streamflow for long periods of time. In places, the Laguna Formation was observed to underlie the terrace deposits. The terrace deposits are considered to be the edge of the meander belt. Bedrock units are considered non-erodible for this study. Bank erodibility factors are presented in the Task 7 report.

Water Engineering and Technology (1990, 1991) tabulated bank erosion sites between Oroville to Verona. Most of these occur along straight sections of stream, mostly because there are more of these. Bank erosion rates varied from less than one foot to over 26 feet per year. Bank erosion sites and rates are discussed in detail in the Task 5 report. Figure 5.7-3 (WET 1991) shows the percent of eroding banks between RM 21 and RM 61.

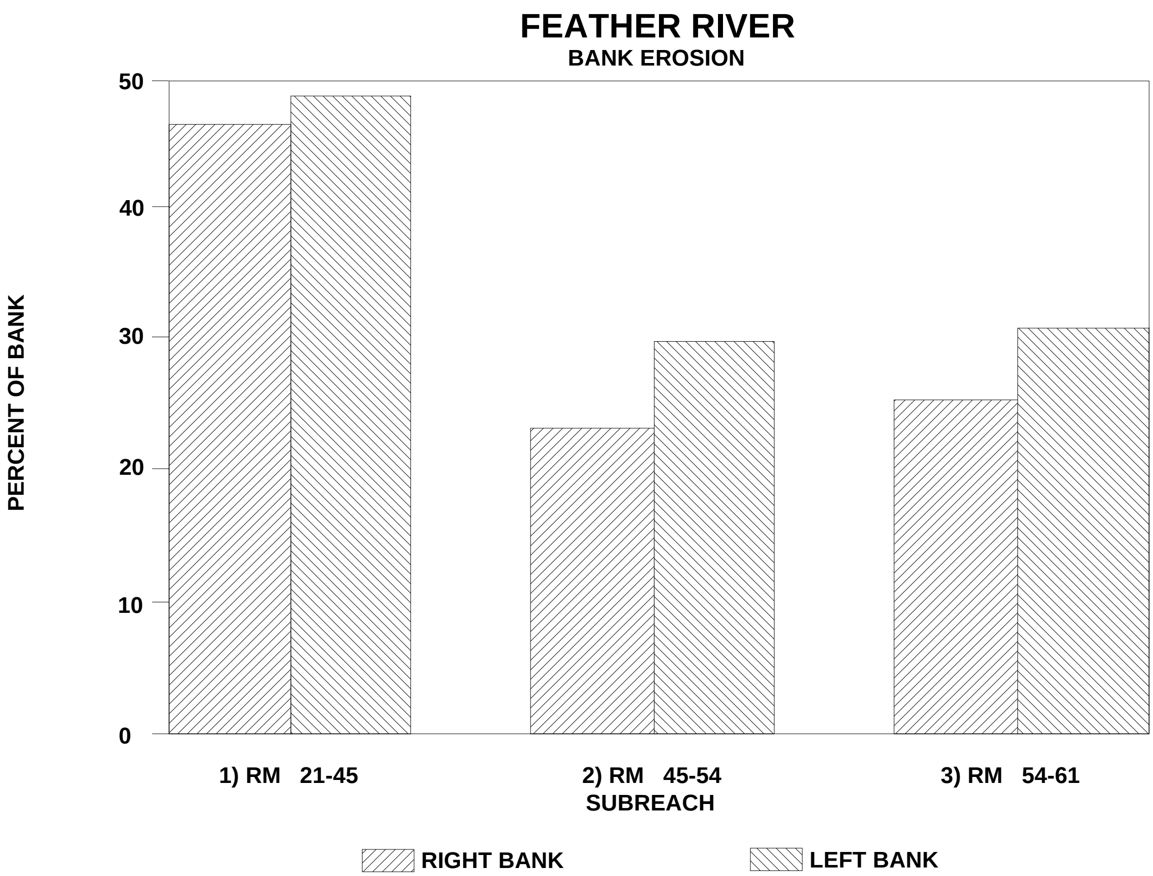

Figure 5.7-3. Percent of eroding banks between RM 21 and RM 61.

Bank protection has been installed in a number of places. These are plotted in the Oroville Facilities Relicensing GIS database. Figure 5.7-4, adapted from WET (1990), shows the percent of banks in FR-1 to -4.

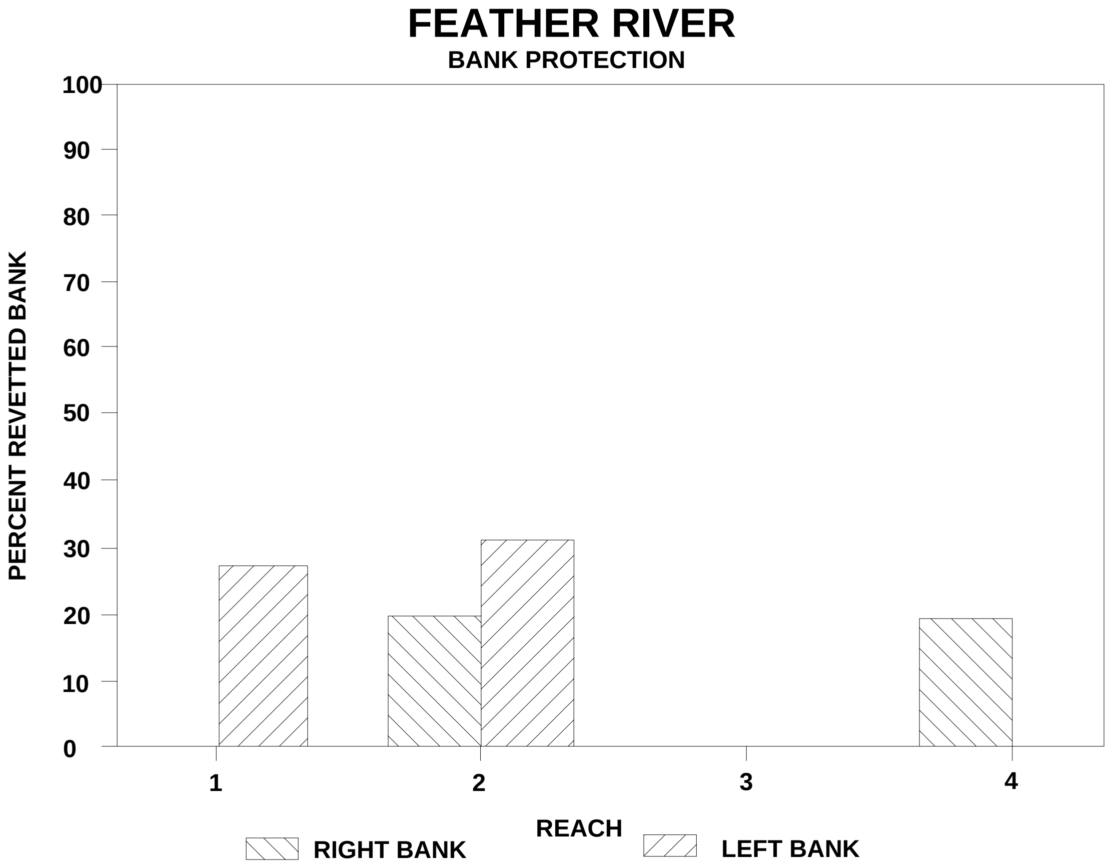

Figure 5.7-4. Percent of bank protection in study reaches FR-1 to FR-4.

5.7.2.8 Bed Characteristics

Bed composition varies in a downstream direction. As in all rivers, there is a general downstream decrease in substrate size. The upper part of the river, from Oroville to Gridley, is mostly a combination of boulders, cobbles, and gravel. Below Gridley to the mouth, the substrate is mostly sand.

Bed composition also varies locally depending on hydraulic and geomorphic variables. Pools tend to have smaller grain sizes than neighboring riffles and runs. For example, fine gravel is present on point bars and riffles below Gridley, but most of the pools, runs, and glides are composed of sand. Table (Rosgen Level II Table) shows the substrate compositions. Compositions were determined by visual examination of the bed surface. Between Gridley and

Verona, geologic data suggests that, below the movable sand bed, the river is incised into the hydraulic mine slickens.

5.7.2.9 Large Woody Debris

Large woody debris (LWD) is now considered an important component of aquatic ecosystems that plays several important ecological roles. Debate had raged over large woody debris in streams for many years. Historically, any and all woody debris in streams has been viewed as an unsightly barrier to fish passage, as well as a navigational hazard in larger rivers. However, in recent decades, it has been realized that LWD removal could adversely affect fish habitat (Bisson et al. 1987; Murphy et al. 1986), alter channel morphology (Robison 1988), and increase sediment routing (Sedell et al. 1988).

The relative importance of any particular role that LWD plays in an aquatic ecosystem varies with stream size, especially in the active channel of a relatively large riverine system (Bilby and Ward 1989). In small and moderately - sized streams (order I and II streams), the ecological and physical functions are dramatic, with LWD the primary mechanism in channel morphology, sediment and nutrient retention, slope stability, and stream productivity (Curran and Wohl 2003). In these smaller streams, it has been found that residence time and stability are primarily dependent on length relative to the width of the stream (Hyatt and Naiman 2001; Bilby and Ward 1989). Residence time and stability of LWD in larger streams appear to be dependent on variables other than the LWD length to stream width ratio, and includes the prevailing flood intensity, channel morphology of the river, and the characteristics of each piece of LWD. Braudick and Grant (2000) found that diameter was one of the strongest controls on LWD stability within larger streams, with the minimum stable diameter around four inches (10 cm). Oddly enough, they found that, hydraulically, overall length was not a significant factor in stability of LWD in larger streams. Rather, diameter, orientation to streamflow and the absence or presence of rootwads were found to be the most significant controls to LWD stability.

Large woody debris can influence channel properties, by creating backwaters, local scour, and pools (Manga and Kirchner 2000; Robison and Beschta 1990), vital summer and overwintering refugia for migrating salmonids and resident fishes (Leicester 2003). Sediments are readily trapped by near - bank LWD, a function some consider the primary mechanism of riparian area creation (Bisson et al. 1987). Additionally, large debris jams may have once played a major role in floodplain and channel development (Sedell and Luchessa 1981, as cited by BioAnalysts 2000).

The decay products from LWD provide organic carbon and energy sources, essential for the food web of the aquatic ecosystem. It provides a stable base for the colonization of algae, which use nutrients from the substrate and the water column, and macroinvertebrates, which feed on the algae and provide food for other organisms. LWD can also contribute to the reduction of nutrient loading by providing backwater and pool habitat for aquatic macrophytes, which strip the water column of nutrients, thereby reducing the nutrient loading downstream.

An analysis of Large Woody Debris was performed for this study and the data is included as Appendix B. The analysis focused on the potential effect of the presence of project facilities on the recruitment of large woody debris to the Lower Feather River.

The criteria for inclusion as large woody debris was set at four inches (10 cm) diameter and 6.5 ft (2.0 m) in length, based on prior studies (Braudick and Grant 2000; Fischenisch and Morrow 2000; O'Connor and Ziemer 1989). While these sizes are commonly used in LWD studies, there are various standards that could be applied for other research goals.

Characteristics of each piece was recorded, including diameter class, estimated length class, absence/presence of the rootwad, location, position of rootwad, orientation to streamflow, and angle to streamflow. The types of LWD were classified as either 'cottonwood', 'oak', 'orchard species', 'conifer', 'other', and 'unknown'.

The position of each piece was recorded with a Garmin GPS Map76A and imported into ArcView GIS 3.2 for mapping. The position was then classified according to the type of mesohabitat. The resulting points were then compared by mile, river reach, and mesohabitat.

A total of 67.13 stream miles were surveyed by boat for large woody debris in the summer and fall of 2003. This survey found 6,954 pieces of LWD in the lower Feather River, an average of 103.8 pieces of LWD per river mile ranging from a low of 16 pieces at Mile 14 to a high of 573 pieces at Mile 34 (Table 5.7-3).

The LWD across four reaches of the Feather River are unevenly distributed as shown in Figure 5.7-5. The Feather River below the Yuba River (Mile 0 to Mile 28) has a total of 1345 pieces of LWD over 28 miles, an average of 48.1 pieces of LWD per mile. The amount of LWD per mile ranges from 15 pieces of LWD in Mile 14 to 83 pieces of LWD in Mile 0. This represents a fairly low abundance of LWD. These reach of the Feather River tends to be deeper and slower, with higher sediment loads for most of this reach than in the upper reaches. At the confluence with the Sacramento River, the Feather River is very shallow, with large sand and sediment bars blocking boat traffic at the mouth during lower flows. Long stretches of bank in this reach have been hardened with levees for flood control or rocked for bank protection, with consequent reductions in riparian vegetation and long stretches of bank devoid of vegetation.

The Feather River from the Yuba River to Honcut Creek (Mile 28 to Mile 44) has a total of 3815 pieces of LWD over 16 miles, an average of 238.5 pieces of LWD per mile. The amount of LWD per mile ranges from 88 pieces of LWD in Mile 28 to 573 pieces of LWD in Mile 34. This reach has a significantly higher amount of LWD than the other three reaches, with over double the amount found in any other reach. This reach of the Feather River, while less than one - fourth (23 percent) of the total river miles, has over 56 percent of all of the LWD found in the River. Within this reach, the six - mile section of the River from Mile 29 to Mile 35 has one - third (32 percent) of all of the LWD found in the lower Feather River.

Above the Yuba River, LWD is very abundant in the Feather River. The majority (>56 percent) of the LWD in the 67 miles of river below the Fish Barrier Dam is found in the sixteen - mile stretch between the mouth of the Yuba River and Honcut Creek. The river banks in this area are not hardened to the same extent as the banks below the Yuba River, with broad areas of riparian vegetation, point bars, and extensive orchards on both banks. Additionally, the amount of LWD in the river mile immediately upstream of the confluence with the Yuba River is more than three times the amount found in the river mile immediately downstream of the confluence. The confluence with Yuba River could be acting as a hydraulic dam, while the Yuba River watershed does not appear to be a major source of woody debris. Conversely, the amount of LWD in the river mile immediately downstream of Honcut Creek is double the amount found immediately upstream. Honcut Creek could be a major source of LWD recruitment into the Feather River.

The river from Honcut Creek to the Afterbay Outlet (Mile 44 to Mile 59) has a total of 1566 pieces over 15 miles, an average of 104.4 pieces per mile. The amount of LWD per mile in this reach ranges from 35 pieces in Mile 54 to 223 pieces of LWD within Mile 47. The section of the River just below the Afterbay Outlet has a significantly higher amount of LWD than the mile just upstream of the Outlet, with 128 pieces of LWD within Mile 58 versus 18 pieces of LWD within Mile 59. In this reach, there is a moderate amount of LWD, with less than half the amount found downstream of Honcut Creek. The portion of this reach that is within the project area has depressed numbers of LWD, primarily due to the presence of the hydraulic mining tailings and levees. Riparian areas are not well - developed in much of this reach.

The river above the Afterbay Outlet to the Fish Barrier Dam (Mile 59 to Mile 67) has a total of 228 pieces over 8 miles, an average of 28.5 pieces per mile. This reach was found to have the lowest amount of LWD of the four reaches, with a low of 16 pieces in Mile 60 and a high of 53 pieces in Mile 64. There was no LWD from Mile 67 to the Fish Barrier Dam (a distance of 0.13 miles), and is not included in the analysis. While much of this reach passes through the City of Oroville from Miles 65 to 67, the river - miles with the lowest amount of LWD was found below Mile 64 within the Oroville Wildlife Area.

The characteristics of most of the LWD pieces were not readily identifiable, due to submersion, inaccessibility, or the bad condition of the piece. Of those pieces that were identifiable, orchard trees (64 percent) predominated, while cottonwoods and oaks comprise another 20 percent. The remainder, willows and sycamores, were a minor component (~4 percent). Coniferous LWD were not spotted in the Lower Feather River during this survey, though this does not preclude their presence. Virtually all of the pieces had a rootwad or a remnant of a rootwad, with only 6% found lacking one. These pieces tended to be the middle section of highly degraded logs and a few exceptions that were clearly sawn off. Rootwads without an attached trunk were infrequent but present. These tended to be in the shallows of the near - bank environment or in the center of the channel. On those pieces that were submerged, diameter and length could not be confirmed, though medium diameter class and length class C appeared to dominate. Approximately 10 percent of the pieces reached the large diameter.

The greater part of the LWD in the Feather River was found associated with one of the two banks (~84 percent), rather than the mid - channel (~16 percent) as shown in Figure 5.7-6. Bank - associated LWD was fairly evenly divided between the right bank (48 percent) and the left bank (52 percent). In 54 percent of this bank - associated LWD, the rootwad of each piece was found located in the channel at the near - bank at the edge or near - bank location, as opposed to the on - bank location. Most of these pieces (over 88 percent) with the rootwad at the near - bank location were found to be parallel to the streamflow, whereas 60 percent of the on - bank pieces were parallel to the streamflow.

LWD tended to be associated with the glide type of riverine habitat (69 percent). This does not appear to be that significant, though, since glides comprise 73.3 percent of the river's area. The highest amount of LWD per acre was found in the riffle habitat, with 4.17 pieces of LWD per acre.

Table 5.7-3. Large Woody Debris on the Lower Feather River.

Reach	# of Miles in Reach	Total LWD	Mean LWD/Mile	Low	High
FR below Yuba River	28	1345	48.1	15	83
FR from Yuba River to Honcut Creek	16	3815	238.5	88	573
FR from Honcut Creek to Afterbay Outlet	15	1566	104.4	35	223
FR from Afterbay Outlet to Fish Barrier Dam	8	228	28.5	16	53

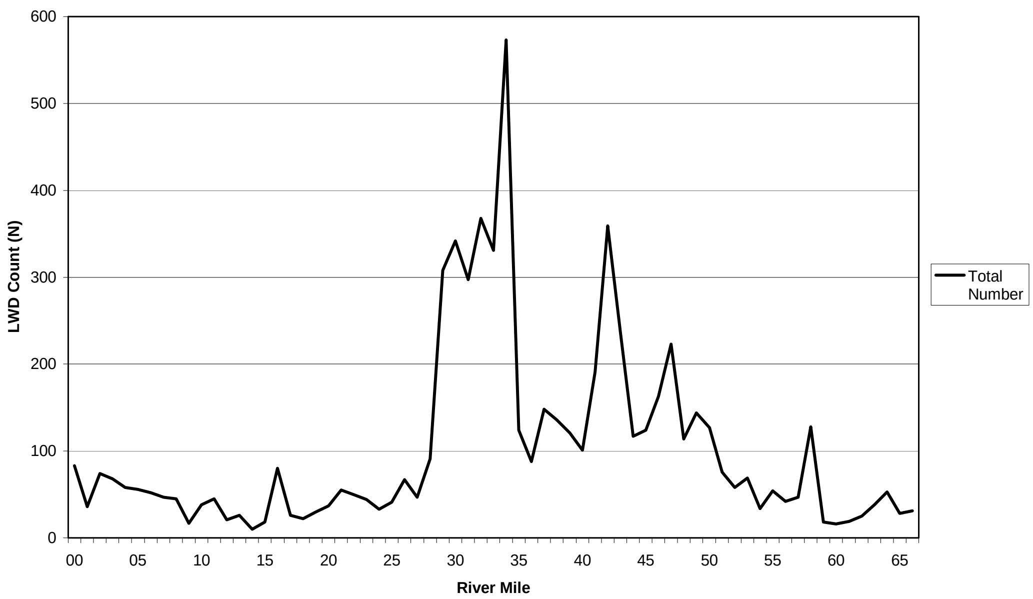

Figure 5.7-5. Lower Feather River LWD, Total Amount by River Mile

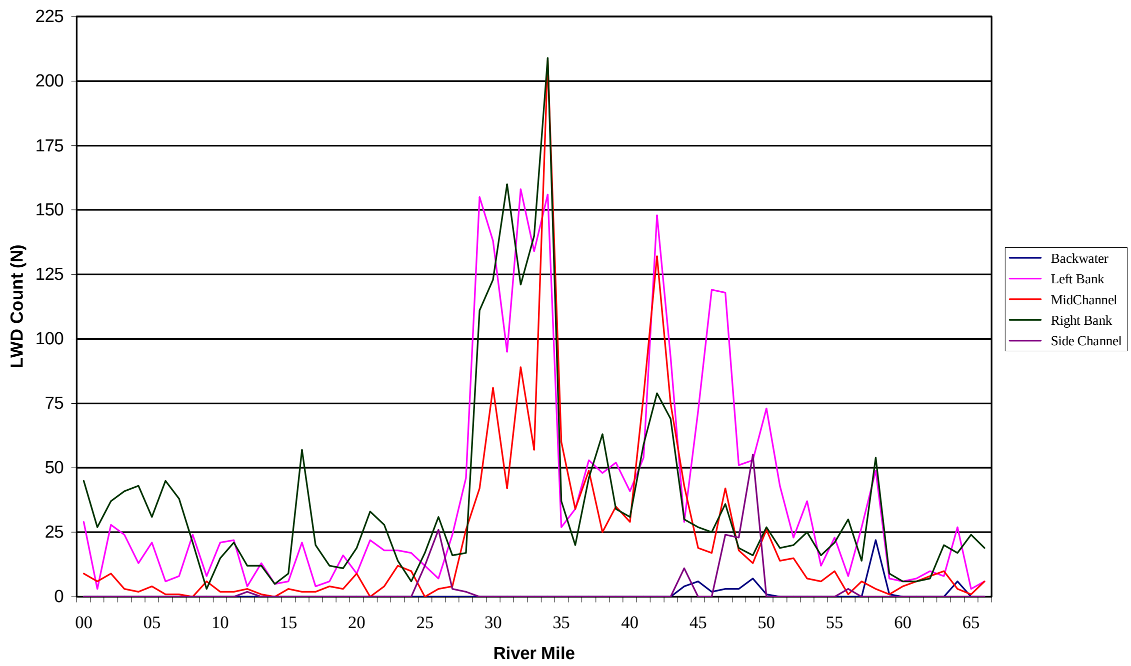

Figure 5.7-6. Lower Feather River LWD, Amount and Location by River Mile

5.8 HYDROLOGY

Natural watershed systems exist in dynamic equilibrium. All the components of a fluvial system such as flow, gradient, channel length, width, and depth, channel bedforms, and floodplains evolve together. These components control the erosion rate, sediment transport, and depositional patterns. Equilibrium may be upset by various land use practices such as cattle grazing, road construction and timber harvesting, or channel modifications such as dams and diversions. Small changes in one place along a stream may have larger effects elsewhere as hydrologic forces attempt to return to an equilibrium state.

Prior to land and water uses that began in the 1850s, runoff flowed unchecked across mountain meadows and down canyon channels onto the floor of the Sacramento Valley. High flows from winter rain and spring snowmelt sharply contrasted with the low base flows of summer and fall. In the upper watershed where gradients are comparatively gentle, mountain meadows were heavily vegetated and streams followed a meandering pattern. Meadows became floodplains and temporary storage reservoirs, reducing peak flows downstream and the stream's capacity to transport large amounts of sediment. This promoted sediment deposition, groundwater infiltration, and meadow productivity.

The broad alluvial valleys, bounded by volcanic ridges in the eastern topographic area, have been considerably altered from their pristine condition. In 1934, John E. Hughes, Junior Forester, Plumas National Forest, described the condition of natural meadow - stream systems (SCS, 1991). "Originally the meadows were well watered by meandering streams whose courses were often concealed by thick vegetation. The streams ran through numerous deep pools covered by lily pads; and in the spring, water stood over practically the entire area of many of the meadows, while the water table was high, even in summer, because the drainage channels were shallow."

After 140 years of water resource development and intensive land use in the watershed, the natural hydrology has been substantially altered. This is evident in the accelerated erosion rates, stream bank degradation, loss of riparian vegetation, head - cutting and gully formation, de - watered aquifers, and sedimentation in downstream reservoirs. This is particularly apparent and well documented in the eastern portion of the North Fork Feather River watershed (DWR 1994). Reservoirs such as Lake Almanor and Lake Oroville, in turn, have reduced flood flows downstream and in the valley below. Streams downstream of reservoirs are also affected. Hydraulic alteration, primarily caused by the attenuation of peak flows, increased summer flows, and diversions, affect stream processes such as sediment transport, riffle - pool - run ratios, riparian vegetation, bar development, bank erosion, and others. Sediment is trapped in reservoirs, resulting in sediment starvation in the streams below the dams.

5.8.1 Water Resources Development

There are numerous reservoirs in the watershed. Most are owned and operated by PG&E and the Department of Water Resources. Table 5.8-1 (DWR 1994) shows the jurisdictional size dams.

Table 5.8-1. Jurisdictional Dams in the Feather River Watershed.

Name of Dam or Reservoir	Name of Stream	Drainage Area (Sq. Mi.)	Reservoir Area (Acres)	Storage Capacity (Ac - Ft)	Crest Elevation (Ft)	Year Completed
Antelope	Indian Creek (EBNFFR)	71	890	21,600	5,025	1964
Bidwell Lake (Round Valley Reservoir)	North Canyon Creek (EBNFFR)	9.12	400	4,800	4,495.6	1865

Table 5.8-1. Jurisdictional Dams in the Feather River Watershed.

Name of Dam or Reservoir	Name of Stream	Drainage Area (Sq. Mi.)	Reservoir Area (Acres)	Storage Capacity (Ac - Ft)	Crest Elevation (Ft)	Year Completed
Bucks Diversion	Bucks (NFFR)	30.6	136	5,843	5,039.5	1928
Bucks Storage (Bucks Lake)	Bucks Creek (NFFR)	28	1,827	103,000	5,178.5	1928
Butt Valley	Butt Creek (NFFR)	75	1,600	53,120	4,144	1924
Caribou Afterbay	North Fork Feather River	616	42	3,400	2,985	1959
Chester Diversion	North Fork Feather River	113	15	75	4,610	1975
Cresta	North Fork Feather River	1,872	62	4,400	1,680	1949
Eureka Lake	Eureka Creek (MFFR)	0.64	42	400	6,200	1866
Fish Barrier Dam	Feather River	3,640	52	580	181	1964
Frenchman	Little Last Chance Creek (MFFR)	82	1,470	51,000	5,607	1961
Grizzly Creek	Grizzly Creek (NFFR)	50.5	11	140	5,054	Unknown
Grizzly Forebay	Grizzly Creek (NFFR)	12.6	38	1,112	4,337.8	1928
Grizzly Valley (Lake Davis)	Big Grizzly Creek (MFFR)	44	4,000	83,000	5,785	1966
Mt. Meadows Reservoir	Hamilton Creek (NFFR)	158	5,800	24,800	5,045.7	1924

Table 5.8-1. Jurisdictional Dams in the Feather River Watershed.

Name of Dam or Reservoir	Name of Stream	Drainage Area (Sq. Mi.)	Reservoir Area (Acres)	Storage Capacity (Ac - Ft)	Crest Elevation (Ft)	Year Completed
Lake Almanor	North Fork Feather River	503	28,257	442,000	4,515	1927
Lake Madrone	Berry Creek (NFFR)	14.9	25	200	1,985.5	1931
Lake Oroville	Feather River	3,611	15,500	3,484,000	922	1968
Long Lake	Gray Eagle Creek (MFFR)	1.13	141	1,478	6,531	1938
Little Grass Valley	Little Grass Valley Cr. (SFFR)	25.9		94,600		1961
Lost Creek Reservoir	Lost Creek (SFFR)	14.1		5,780		1924
Lower Three Lakes (Three Lakes)	Milk Ranch (NFFR)	1.5	44	606	6,084	1928
Palen	Antelope Creek (MFFR)	10.6	12	146	5,030	1951
Philbrook	West Branch (NFFR)			5,010		
Poe	North Fork Feather River	1,950	52	1,150	1,390	
Ponderosa	South Fork Feather River	108		4750		1958
Rock Creek	North Fork Feather River	1,700	80	4,660	2,220	1961
Round Valley	North Fork Feather River	2.17	90	1,285	5,498	1950

Table 5.8-1. Jurisdictional Dams in the Feather River Watershed.

Name of Dam or Reservoir	Name of Stream	Drainage Area (Sq. Mi.)	Reservoir Area (Acres)	Storage Capacity (Ac - Ft)	Crest Elevation (Ft)	Year Completed
Silver Lake	Silver Creek (EBNFFR)	1	120	650	6,000	1877
Sly Creek	Sly Creek (SFFR)	24		65,200	3,551	1906
Spring Valley Lake	Rock Creek (NFFR)	.25	15	75	6,314	1961
Taylor Lake	Tributary to Indian Creek (EBNFFR)	.36	36	380	7,000	Unknown
Thermalito Afterbay	Tributary Feather River	13.3	4,550	57,500	142	1929
Thermalito Diversion	Feather River	3,640	330	13,400	233	1967
Westwood Mill Pond	Robbers Creek (NFFR)	40	112	660	5,074	1914

Table 5.8-2. Department of Water Resources Facilities.

Reservoir	Storage (acre - feet)	Location
Antelope Lake	22,570	North Fork Feather Indian Creek
Frenchman Lake	55,480	Middle Fork Feather Little Last Chance Creek
Lake Davis	84,370	Middle Fork Feather Grizzly Creek
Lake Oroville	3,537,580	Feather River nr. Oroville

The Department of Water Resources operates three reservoirs (Table 5.8-2) in the upper watershed, Frenchman, Davis, and Antelope lakes in addition to the Lake Oroville facilities. Project facilities also include the Thermalito Diversion Pool, the Thermalito Forebay (11,400 acre - feet), and the Thermalito Afterbay (61,100 acre - feet).

Of the many reservoirs that occur in the watershed, two have a major effect on streamflow. Lake Almanor controls flows in the upper part of the North Fork. Lake Oroville and appurtenant structures impounds the North, Middle, and South Forks Feather River near the town of Oroville.

5.8.2 Stream Discharge above Lake Oroville

The largest flows in un-dammed streams occur during the winter in response to rain, and in the spring and early summer in response to snowmelt. The lowest flows occur during late summer and early fall. The combined North and Middle Fork mean discharge to Lake Oroville is approximately 7,555 acre - feet per day, or 2.76 million acre - feet per year. Total average yearly yield to Lake Oroville was 6284 cfs for the 1969 to 2000 water years.

Table 5.8-3 is a list of gaging stations representing flows of major forks and tributaries entering Lake Oroville.

Table 5.8-3. Gaging Stations of Streams entering Lake Oroville.

USGS Station Number	Station Name	Period of Record	Drainage Area (mi^2)	Average Yearly Discharge (cfs)	Elevation above datum(ft)
11399500	Feather River, North Fork, near Prattville	1906 - 1991	493	401	4,390
11396350	South Fork Feather below Ponderosa Dam	1962 - 1965	108	580*	
11405300	West Branch Feather near Paradise	1957 - 1965	113	511	
11404900	Feather River, North Fork, below Poe Dam, near Jarbo Gap	1967 - 1991	1,942	2,325	1,306
11392500	Feather River, Middle Fork, near Clio	1925 - 1979	686	283	4,380
11394500	Feather River, Middle Fork, near Merrimac	1951 - 1986	1,062	1,484	1,560
*adjusted for diversion to Miners Ranch Canal, water years 1964 - 65					

All USGS gaging stations on the Middle Fork and its tributaries have been discontinued but there are 19 active USGS gaging stations on the North Fork and its tributaries. The lack of streamflow data on the Middle Fork is likely attributable to difficult access and the absence of hydroelectric generation.

Average monthly flows for the period of record are presented for the North Fork, Middle Fork, South Fork, and for gaging stations below Lake Oroville.

5.8.3 Mean Monthly Discharge, Flow Exceedance, and Flood Frequency below Lake Oroville

Gaging stations useful for geomorphic analyses of the lower Feather River are shown in Table 5.8-4.

Table 5.8-4. Gaging Stations for the Feather River below Lake Oroville.

GAGE NAME	NUMBER	PERIOD OF RECORD	MEAN FLOW CFS	AREA SQ. MI
Lake Oroville near Oroville	11406800	Nov. 1967 -		3,607
Sum of diversions	na	Nov. 1967 -	1,100	na
Feather River at Oroville	11407000	Oct. 1901 -	6,280*	3,624
Feather River near Gridley	11407150	Oct 1964 - 2001	4,852	3,676
Feather River at Yuba City	11407700	Oct 1964 - 1984	5,812	3,974
Feather River near Nicolaus	11425000	Apr. 1942 - 1983	8,140	5,921

* Adjusted yield for evaporation from Lake Oroville and diversions, 1902 - 2000. Annual yield from 1902 to 1967 is 5830 cfs; from 1967 to 2000 is 1140 cfs.

There are five diversions from Lake Oroville and Thermalito Afterbay. These are the Palermo Canal (11406810) with an annual mean flow of 10.5 cfs, the Western Canal (11406880) with an average annual mean flow of 320 cfs, the Richvale Canal (11406890) with a flow of 127 cfs, the Pacific Gas and Electric Co. lateral Intake with a flow of 644 cfs. The average combined annual diversion from these is about 1,100 cfs. This is about 20 percent of the average annual yield of the Feather River at this point. July has the highest diversion, with the combined diversion averaging 2600 cfs (1967-98).

5.8.3.1 Lake Oroville near Oroville Gage

The Lake Oroville gage shows storage and lake level. It is useful for determining impacts on the streams draining into Lake Oroville and shoreline impacts.

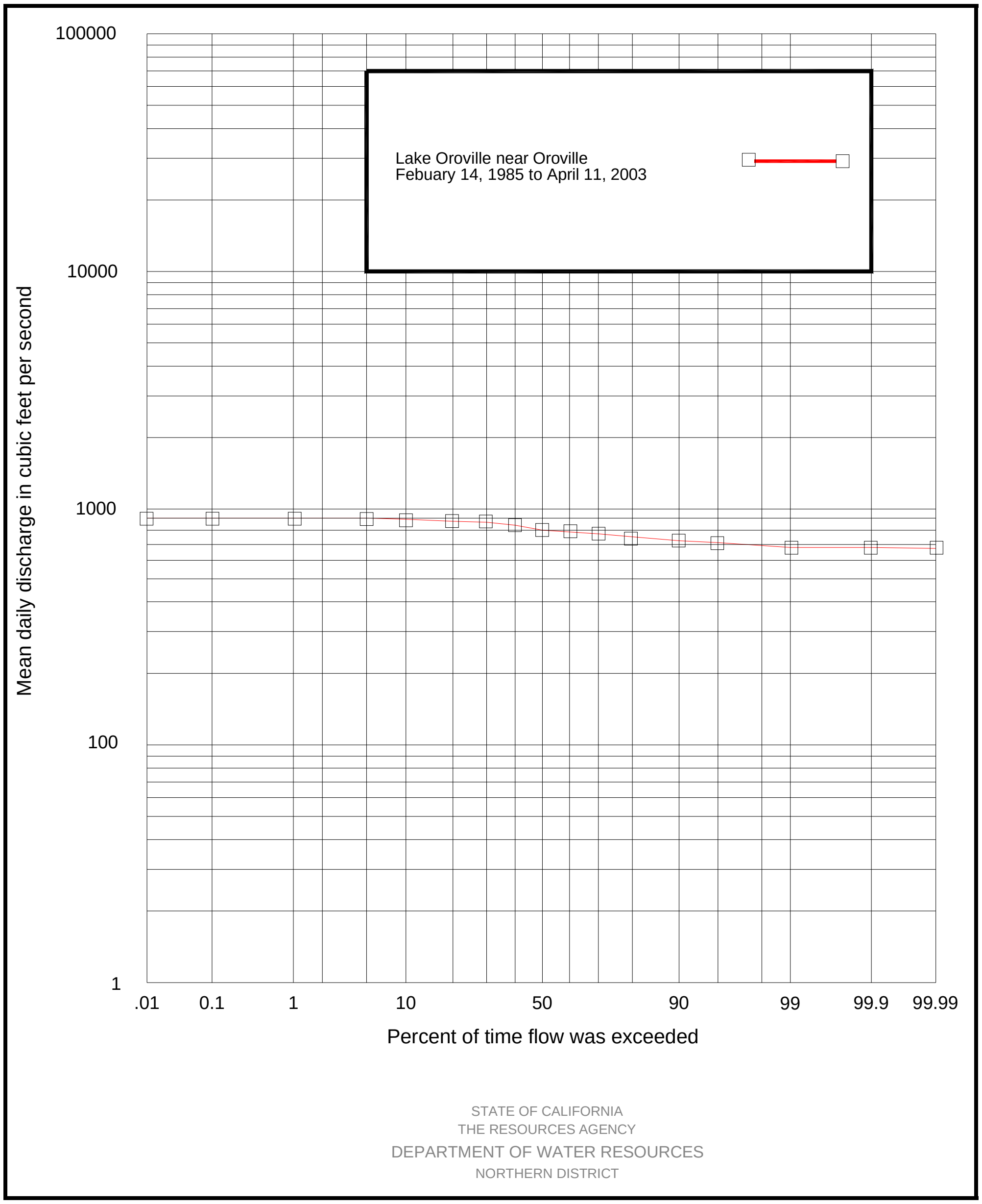

Figure 5.8-1. Lake Oroville near Oroville Lake Level Exceedence Frequency.

5.8.3.2 Feather River at Oroville Gage

The Feather River at Oroville gage is downstream of the Thermalito Diversion Dam. From 1901 to 1967, the gage recorded flows characteristic of pre - dam conditions. The annual mean flow was 5,830 cfs. After 1967, much of the flow was diverted to the Thermalito Afterbay. During most of the year, flows averaging between 500 and 600 cfs occur in the low flow section of the river between the Thermalito Diversion Dam and the Thermalito Afterbay discharge to the Feather River. The annual mean flow in the low flow section of the river is 1140 cfs using 1967 to 2000 water years. The pre - and post Oroville Dam mean monthly streamflow for this gage is shown Figure 5.8-2. This gage best reflects flow conditions in the low flow section between the Thermalito Diversion dam and the Thermalito Outfall. Figure 5.8-3 shows the flow exceedance, and Figure 5.8.4 shows the flood frequency.

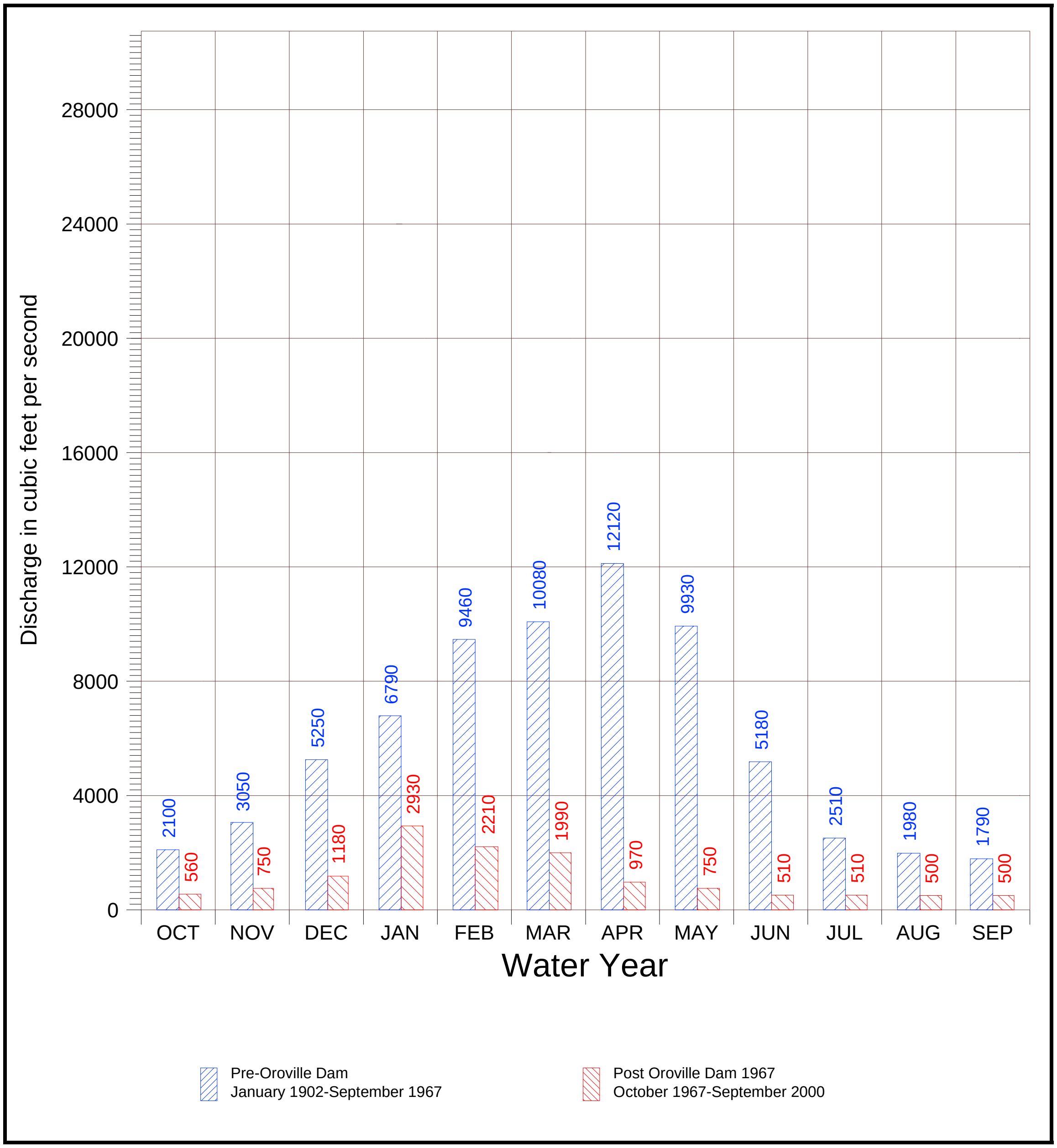

Figure 5.8-2. Feather River at Oroville Mean Monthly Flow Data

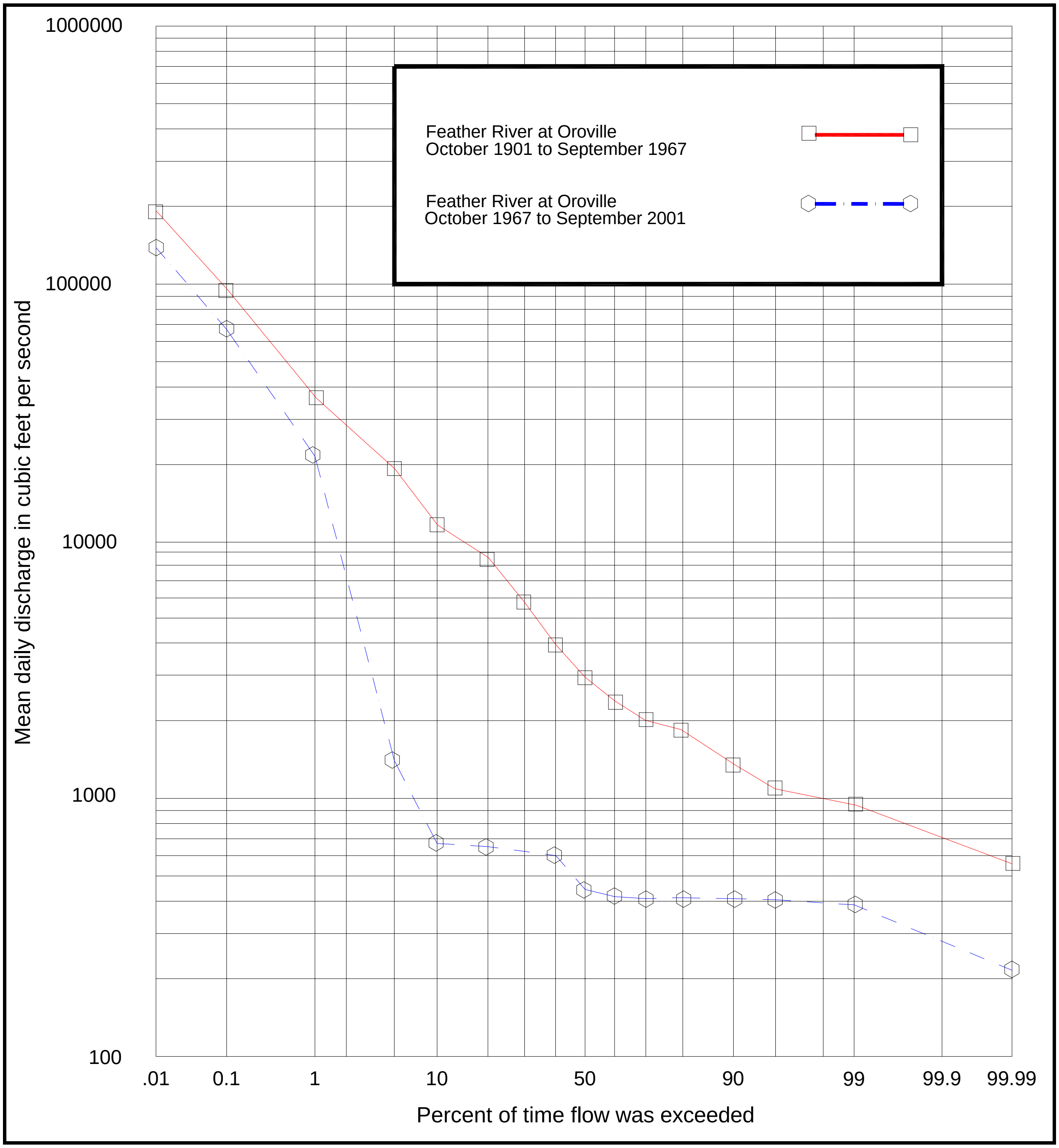

Figure 5.8-3. Feather River at Oroville Flow Exceedence Graph

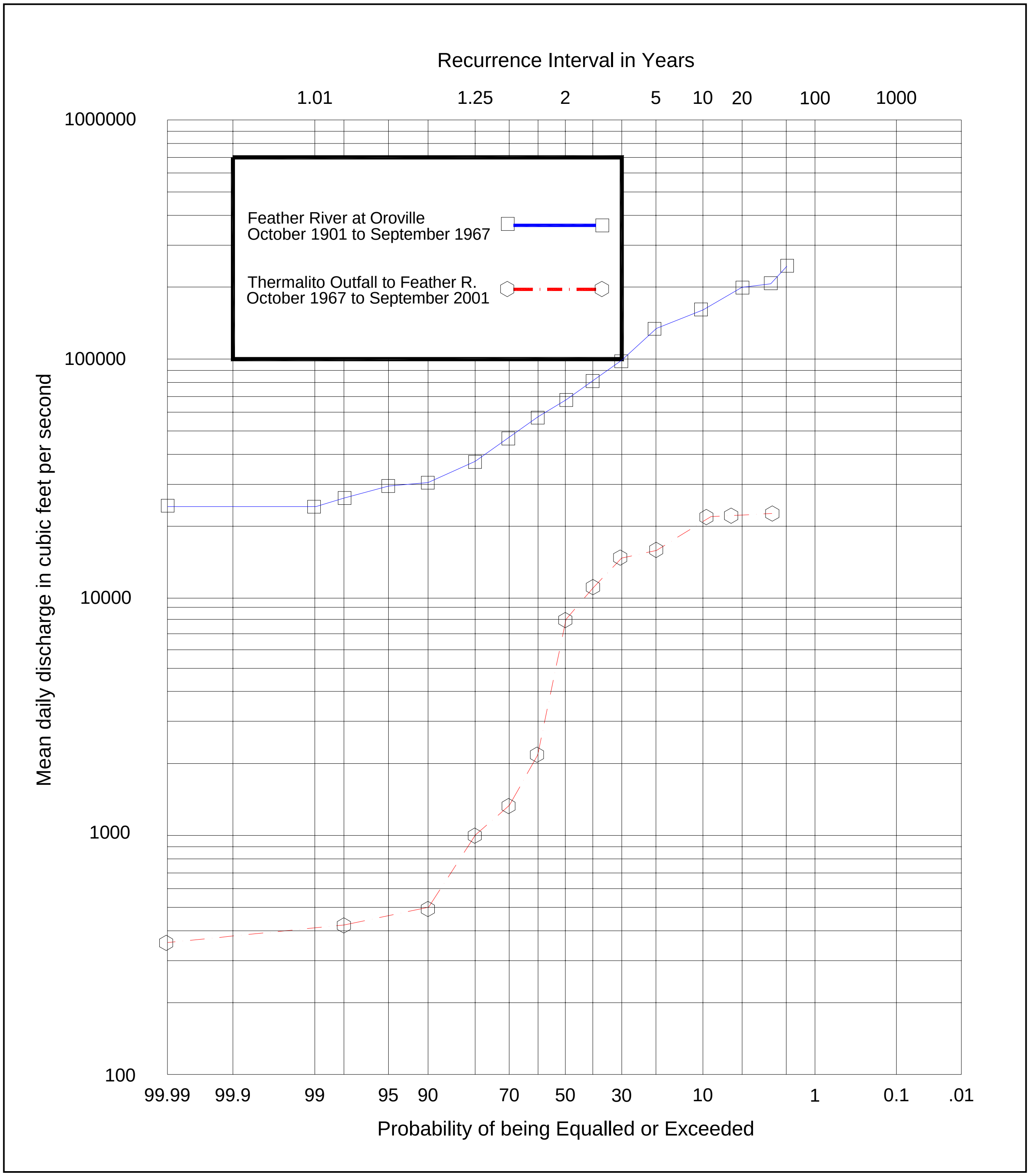

Figure 5.8-4. Feather River at Oroville Flood Frequency Graph.

5.8.3.3 Feather River at Gridley Gage

The Feather River near Gridley gage is about 300 feet upstream of the highway bridge and three miles east of Gridley. The record begins in 1964 and ends in 1998. No tributaries occur between the Oroville gage and Gridley, but the station reflects diversions made upstream. The pre - and post dam changes in mean monthly discharge is shown in Figure 5.8-5 below. The Gridley station best represents flows in the Feather River between the Thermalito outfall and the mouth of Honcut Creek.

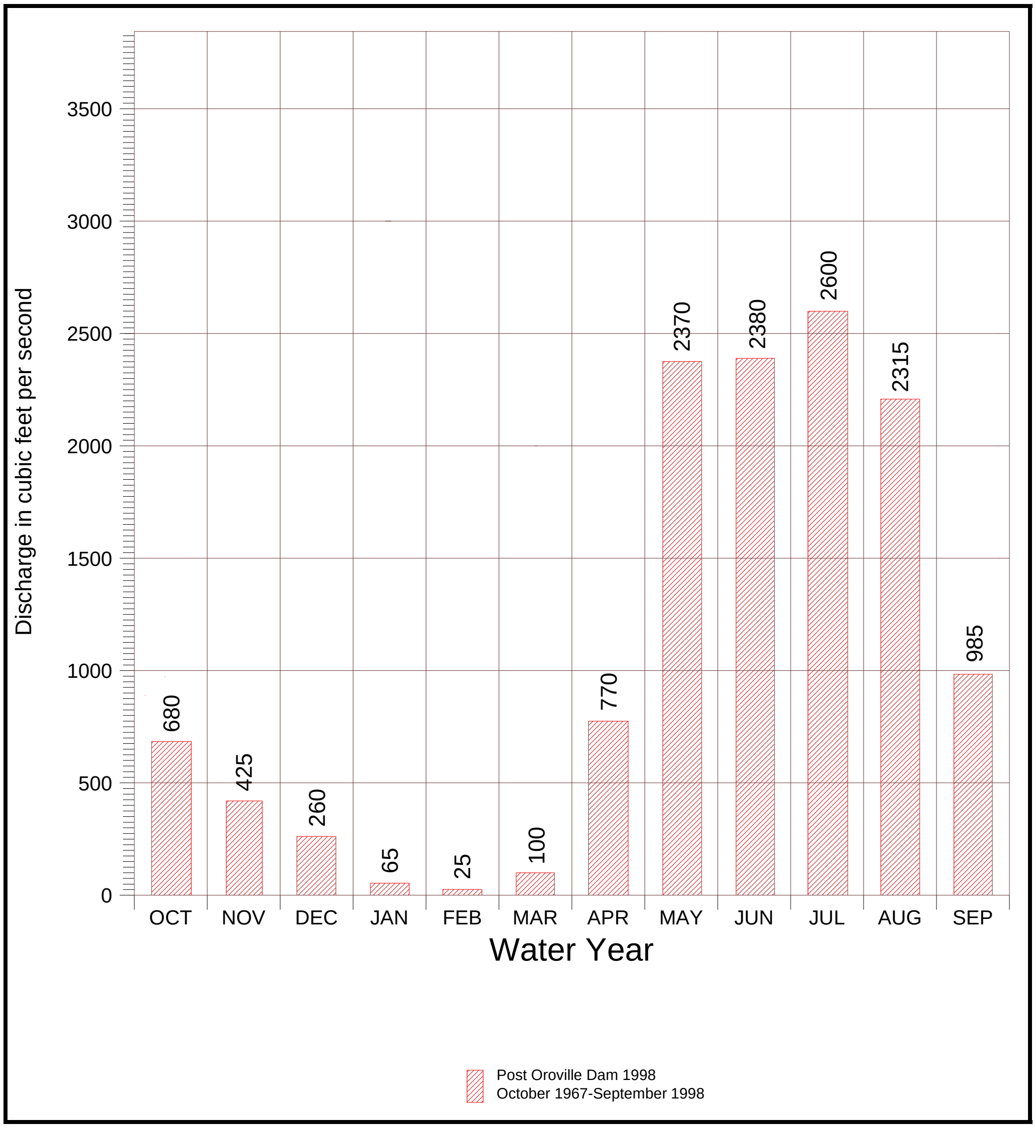

Figure 5.8-5. Sum of Mean Monthly Diversions from Lake Oroville and the Thermalito Afterbay.

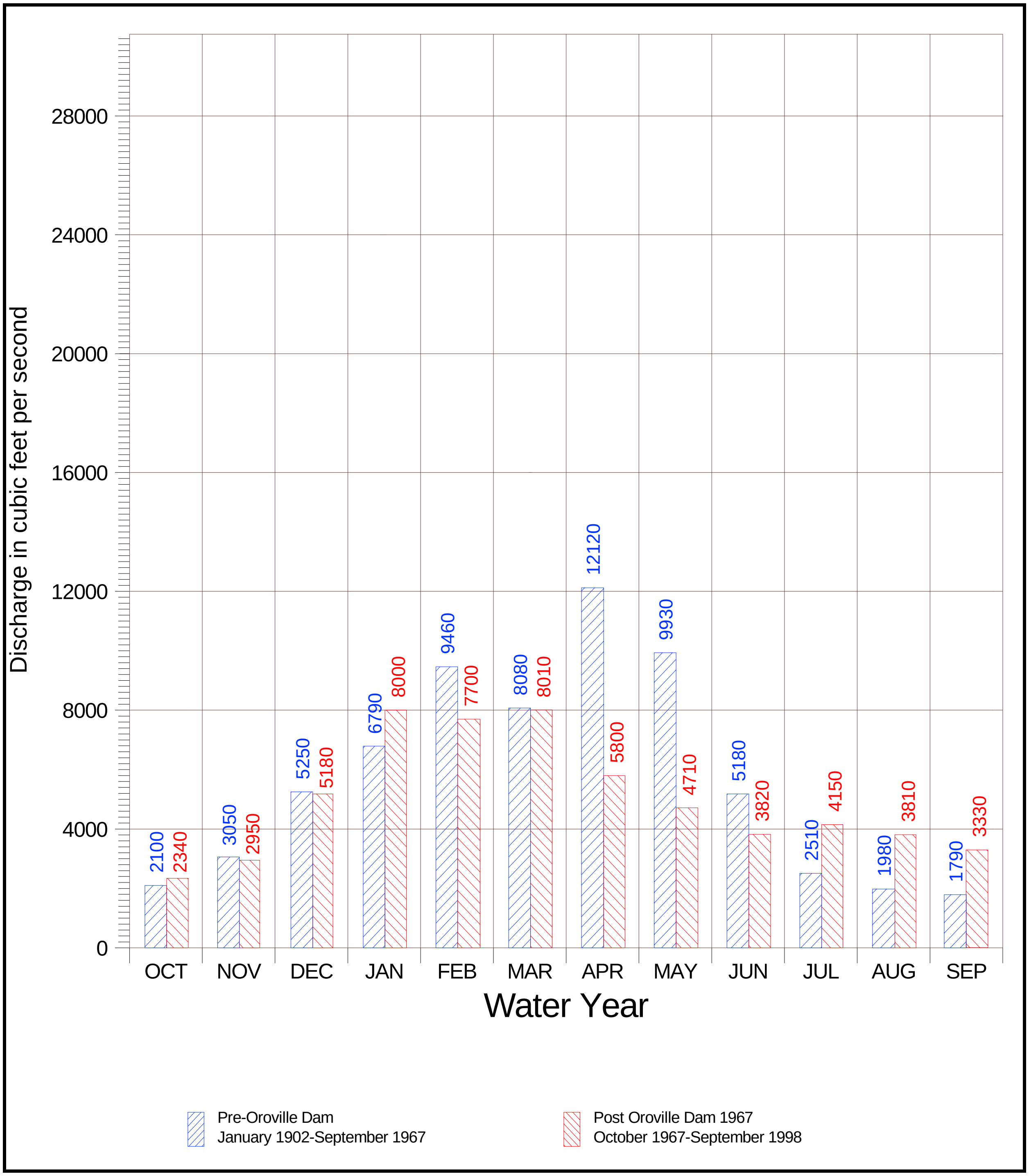

Figure 5.8-6. Feather River near Gridley Changes in Mean Monthly Discharge

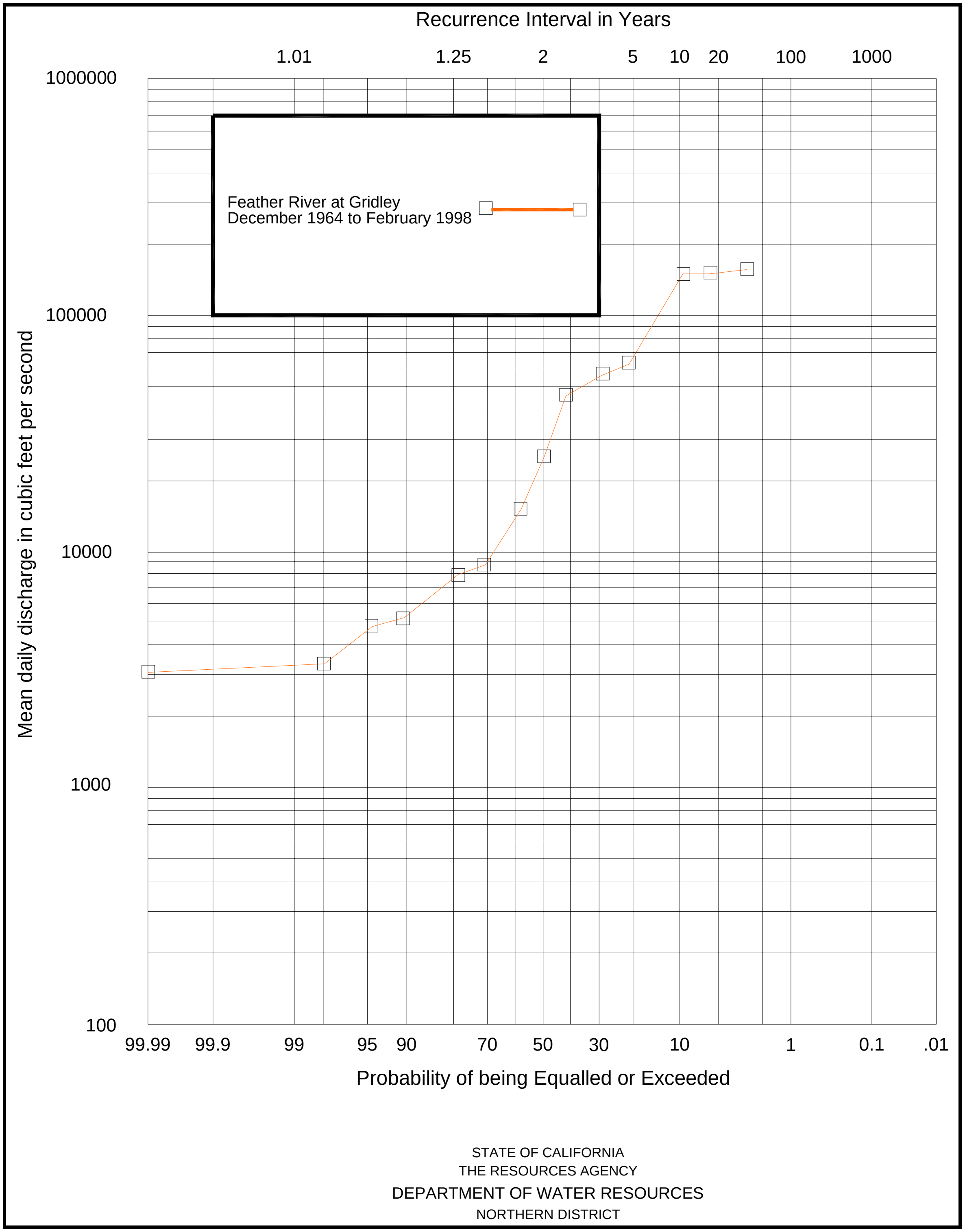

Figure 5.8-7. Feather River near Gridley Flood Frequency

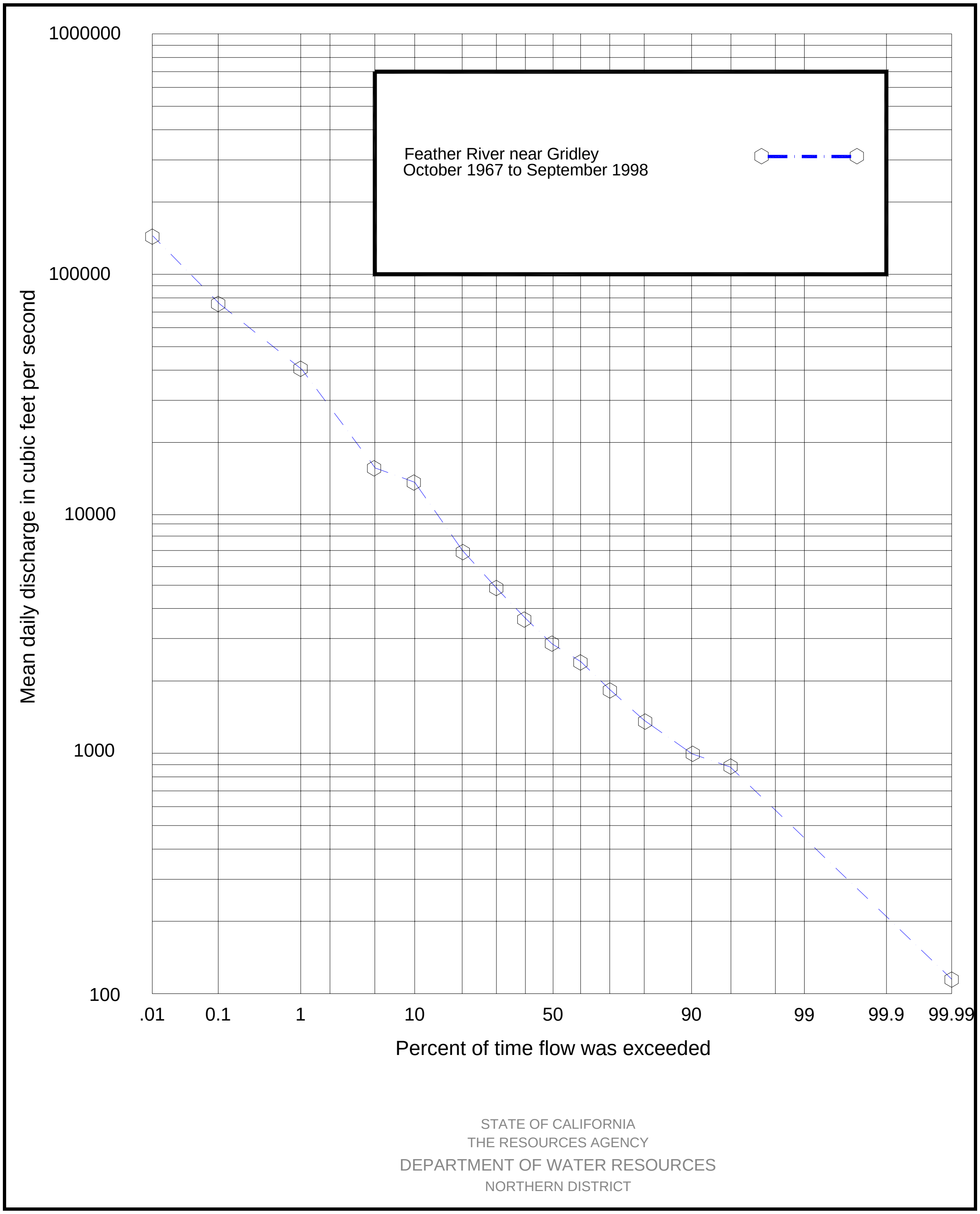

Figure 5.8-8. Feather River near Gridley Flow Exceedance

5.8.3.4 Feather River at Yuba City Gage

The Feather River at Yuba City gage has a limited record that is not as long as the Gridley and Nicolaus gages. The average annual yields are therefore not strictly comparable. However, it does include flow from Honcut Creek and is the best gage to represent flows in the Feather River between the mouth of Honcut Creek and the mouth of the Yuba River.

5.8.3.5 Feather River near Nicolaus Gage

The Feather River near Nicolaus gage is on the left bank 1.7 miles southwest of Nicolaus. It includes the drainages of the Yuba and Bear rivers. The gage best describes flow conditions on the Feather between the mouth of the Bear River (RM 12.3) and the mouth of the Feather at Verona. The gage ceased operation in 1983 after about 40 years of record.

5.8.4 Peak Flows

Peak flows were available for all the stream gages downstream of Lake Oroville. However, the periods of record differed for each station. The Feather River at Oroville gage has the longest period of record. Figure 5.8-9, derived from the U.S. Geological Survey website, shows the peak daily flood flows for this gage. Table 5.8-5 shows the peak daily flow for flood years. Years without flood flows are not shown.

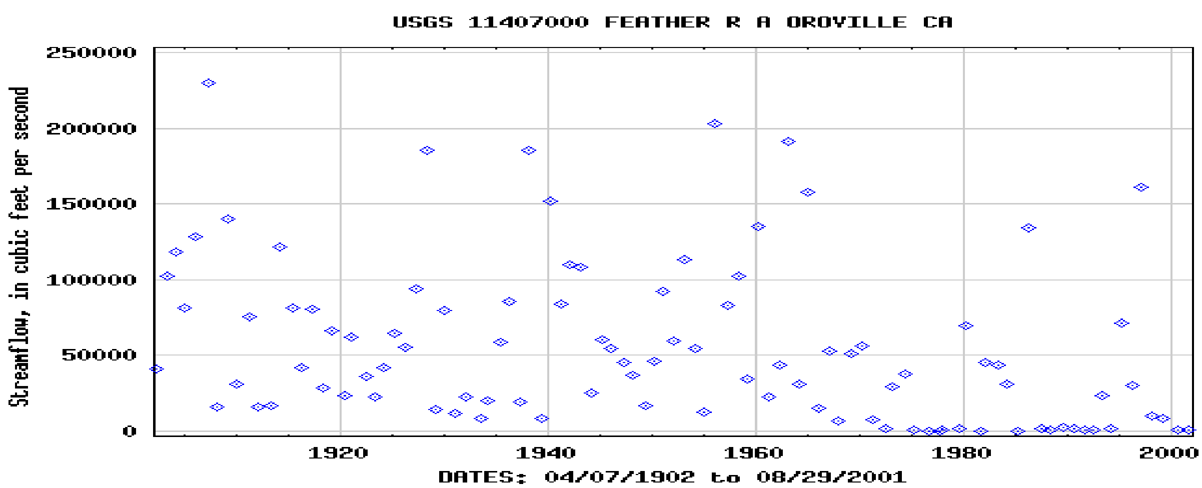

Figure 5.8-9. Peak Flows for the Feather River at Oroville Gage.

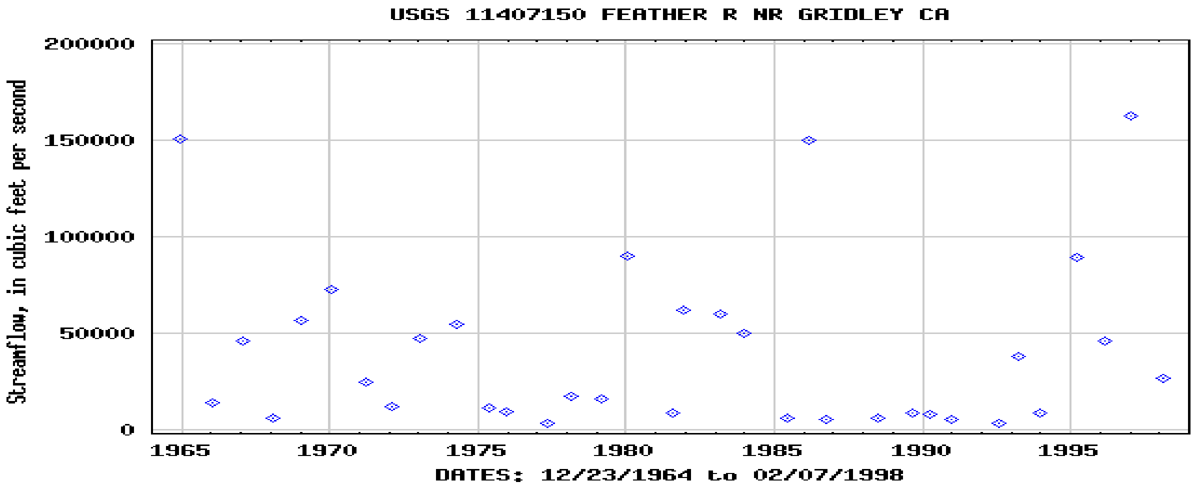

Figure 5.8-10. Peak Flows for the Feather River near Gridley Gage.

Table 5.8-5. Peak Flows for Feather River Gaging Stations.

CALENDAR YEAR	Oroville * 11407000 (1,000 cfs)	Gridley 11407150 (1,000 cfs)	Yuba City 11407700 (1,000 cfs)	Olivehurst 11421700 (1,000 cfs)	Nicolaus 11425000 (1,000 cfs)
1903	102	- - -	- - -	- - -	- - -
1904	118	- - -	- - -	- - -	- - -
1906	128	- - -	- - -	- - -	- - -
1907**	230	- - -	- - -	- - -	- - -
1909	140	- - -	- - -	- - -	- - -
1913	122	- - -	- - -	- - -	- - -
1928	185	- - -	- - -	- - -	- - -
1937**	185	- - -	- - -	- - -	- - -
1940	152	- - -	- - -	- - -	- - -
1942	110	- - -	- - -	- - -	- - -
1943	108	- - -	- - -	- - -	- - -

CALENDAR YEAR	Oroville * 11407000 (1,000 cfs)	Gridley 11407150 (1,000 cfs)	Yuba City 11407700 (1,000 cfs)	Olivehurst 11421700 (1,000 cfs)	Nicolaus 11425000 (1,000 cfs)
1953	113	- - -	- - -	- - -	127
1955**	203	- - -	- - -	- - -	357
1958	102	- - -	- - -	- - -	- - -
1960	135	- - -	- - -	- - -	136
1963	191	- - -	- - -	- - -	264
1964	158	151	182	- - -	281

* 1901 - 1967: Pre - Oroville Project minimum flood flow recorded in table is 100,000 cfs

* * flood event referenced in text

\- - - means no available data

Post - Oroville Dam Peak Flow - - - - - Events

CALENDAR YEAR	Oroville * 11407000 (1,000 cfs)	Gridley 11407150 (1,000 cfs)	Yuba City 11407700 (1,000 cfs)	Olivehurst 11421700 (1,000 cfs)	Nicolaus 11425000 (1,000 cfs)
1967	53.3	45.6	52.8	- - -	96.6
1969	51.1	56.4	48.1	- - -	88.4
1970	56.3	72.9	74.5	133	146
1973	29.7	47	54.6	62.1	72
1974	37.8	54.7	55.3	88	108
1980	69.5	90.1	- - -	105	115
1981	45	61.8	- - -	- - -	148
1983	43.5	60	- - -	- - -	112
1986**	134	150	- - -	- - -	- - -
1993	23.4	37.7	- - -	- - -	- - -
1995**	71.7	89.4	- - -	- - -	- - -
1996	30.2	45.7	- - -	- - -	- - -
1997**	161	163	- - -	- - -	- - -
1998	10.2	26.4	- - -	- - -	- - -

* 1967 - Post Oroville Project minimum flood flow recorded is 10,000 cfs

* * flood event referenced in text

CALENDAR YEAR	Oroville * 11407000 (1,000 cfs)	Gridley 11407150 (1,000 cfs)	Yuba City 11407700 (1,000 cfs)	Olivehurst 11421700 (1,000 cfs)	Nicolaus 11425000 (1,000 cfs)
- - - means no available data					

5.9 SEDIMENT TRANSPORT IN THE LOWER FEATHER RIVER

Streams change their sediment transport with time, typically in response to changes in climate, geologic events, changes in base level, and other factors. The Feather River today is also changing, but mostly in response to human activity. These activities include land use in the upper watershed, hydraulic mining, water diversions, and dams.

Beginning in and about 1850, these human activities have affected hydrologic conditions in the upper watershed, resulting in large changes in water and sediment yields to the lower Feather River. Hydraulic mining introduced massive volumes of sediment into the stream system between the 1850s and 1890s. Later, numerous reservoirs were constructed in the upper watershed, trapping sediment and altering streamflow.

Beginning in 1967, the Oroville Facilities started to regulate the lower Feather River and added to the change in streamflow and sediment discharge. Over 97 percent of the sediment from the upstream watershed is trapped in the upstream reservoirs, resulting in sediment starvation downstream.

Downstream of the Oroville Facilities, the river is affected by the altered streamflow amount and altered distribution pattern, both instrumental in channel formation. These include attenuation of peak flows, decreased winter flows, increased summer flows, and changes the historic flow frequencies.

The larger flows, occurring only a small percentage of the time, transport most of the sediment because suspended sediment transport increases at a rate of about the square of streamflow, and bed material increases as the cube of velocity. Since sediment and streamflow are the primary factors influencing geomorphology, channel changes will occur as the river adjusts to these modified conditions.

Channel cross-sections surveyed by the U.S. Army Corps of Engineers between 1909 and 1911 were resurveyed by the DWR in 1965 and 1969, and then again in 2002 and 2003. These sections show net scour, both widening and deepening. This trend is still continuing, as shown by surveys done by DWR in 2002 and 2003. Detailed descriptions and analysis of these sections are provided in the report *for SP-G2 Task 3 Report*: *Channel Cross Sections and Photography.*

There are no current sediment transport measurements available on Feather River. The Fluvial 12 program develops long-term bedload yields based on sediment transport equations, but these are not actual measurements.

The USGS (1978) report "Sediment Transport in the Feather River, Lake Oroville to Yuba City, California" is the most recent. The USGS compiled and measured (1965-75) suspended sediment discharge at the following stations: Feather River at Oroville; Feather River near Gridley; and the Feather River at Yuba City. No other sediment data was found on either the USGS or DWR websites.

A detailed discussion of sediment transport is presented in the SP-G2 task 7 Report.

6.0 LARGE SCALE EVENTS AND LAND - USE PRACTICES AFFECTING GEOMORPHIC PROCESSES

Prior to the 1850s, resource use in the watershed was limited. Local Native Americans lived in the area and hunted and fished. Their activities did little to change the natural environment although they were known to use fire to clear forest areas. Major resource use began in the watershed in the 1850s, and included livestock grazing, road building, timber harvesting, mining, and farming. Recent activities also include local urban development and varied recreational uses. Current land uses in the study area include timber harvesting, grazing, agriculture, recreation, mining, urban development and hydroelectric development.

The Feather River has in the last one hundred years been affected by a number of human - induced events resulting in physical and ecological changes. These include hydraulic mining, flow diversions, dam construction, levees, dredging, road building, and vegetation manipulation (such as agriculture and timber harvesting). Many of these activities have affected the upper watershed increasing both water and sediment yield.

Human - induced changes to the Lower Feather River, including bank protection, gravel dredging and mining, riparian vegetation removal, dams, flow regulation and flood control, have resulted in a number of physical and ecological effects. The loss of gravel recruited from reaches upstream from Oroville Dam has reduced the spawning gravel available in downstream reaches.

Agriculture and urbanization are the main land use changes affecting the river. Oroville, Marysville, and Yuba City are the major towns built on the Feather River flood plain. The towns are protected by levees that disconnect the river from its ancestral flood plain.

Orchards and field crops have been planted on the rich soils of the remaining floodplain, both outside and inside the levees. Inspection of 1997 aerial photographs show that almost all of the riparian vegetation on the floodplain has been converted to agriculture, and only a minimal percentage of the original riparian vegetation remains.

Removal of riparian vegetation may affect an alluvial stream in a number of ways. Vegetation adds roughness to the channel and overbank areas, reducing velocities and increasing sediment deposition. Vegetation protects soil and reduces erosion. Vegetation on meander bends decreases incidence of cutoffs. Removal of stream bank vegetation reduces the amount of large woody debris in the river.

Land use, primarily logging, road building, and grazing, also affected the upper watershed by changing hydrologic conditions. Increased sediment, run - off, and larger peak flows affected the entire Feather River System. This has largely been ameliorated by Lake Oroville.

6.1 MINING

Mining in the watershed began in the mid - 1800s and continues today, although on a smaller scale. Mineral resources include gold, copper, manganese, silver, chromite, lead, limestone, sand, gravel, and rock. The first miners exploited placer gold deposits in stream gravel. Gravel was dredged and sluiced using water and mercury to separate the gold. Between the 1850s and 1890s, large amounts of sediment were washed into the stream system using high - pressure water jets to erode older gold - bearing formations. High mercury levels in the sediment and in fish are a result of this early mining.

Hard rock mining also produced large quantities of pulverized tailings. Many of these tailings now leach sulfides, which lower stream water pH. Sulfide contamination, by lowering pH, may significantly harm fisheries.

Dredging for placer gold occurred over large areas of what is now the Oroville Wildlife area. Windrows of gravel still remain although considerable gravel has been harvested for the construction of Oroville Dam and appurtenant facilities. Commercial gravel mining is also occurring in the area.

6.1.1 Hydraulic Mining

Hydraulic mining was invented by Edward Matteson (Kelley 1989), who arranged to have water delivered above his claim, and then used water under pressure to wash gold bearing gravels from the hillside into his sluice box. The process was so revolutionary that a miner could do the work in a single day that would normally take many months. The idea spread rapidly, with larger and larger nozzles washing away entire hillsides of clay, silt, sand, and gravel.

In the early 1850's, mining began around the City of Oroville. In the early years, small hydraulic mines cropped up on both sides of the river. In the later 1850's, ditches provided abundant water to the miners, resulting in a spurt of economic activity. Ditches to drain effluent from the mines located in the bluffs behind the town were cut through the city's streets to the river. A plume of hydraulic mining debris discharged into the Feather, producing a long island in front of town. On the north side at Thompson Flat, a new drainage tunnel was completed in 1864. In 1866, a new supply ditch gave the miners far more water, resulting in large increase in debris being washed into the river. Hydraulic mining first caused an initial surge of fine sediment into the channels. Transport downstream in the

Feather River further differentiated the sediment sizes, with a predominance of gravel, sand, and silt in the upper reaches and silt and clay in the downstream reaches. Later, coarser gold bearing deposits were mined, resulting in a large influx of boulders, cobbles and gravel with some fines. Most of this material deposited in the canyons, in the upper river channels, and where the river entered the valley near Oroville. This explains the large volume of cobbles and gravel deposited in the Oroville wildlife area.

In the late 1860s, the pace of mining again stepped up. More powerful equipment was purchased. Bigger drainage ditches and larger nozzles were installed. Increasing amounts of debris were dumped into the river. At the head of Morris Ravine, a few miles upriver from Oroville, the colossal Hendricks mine opened up in 1870. The large monitors hurled tons of water on the mountainside, melting the earth away. Even bedrock was torn up and thrown high in the air. The water and debris streaming out of the mine was caught up by a sluice box four feet wide and a mile long, discharging directly into the Feather River (Kelley 1989).

Streams of sand, gravel, and mud from the mines flowed together into the Feather to bury the stream under an immense moving deposit of debris reaching depths of more than 100 feet. During winter storms, these deposits would mobilize, and a wall of mud and gravel would roar down the canyon. The Feather was choked in sediment, burying vegetation, destroying pools and riffles, and killing fish.

The gravel and cobbles washed out of the canyon and deposited in what is now the Oroville Wildlife Area. The finer sand, silt, and clay deposited farther downstream, choking the Feather and the Sacramento Rivers. Navigation in the Sacramento River became a problem as early as 1856, three years after the tentative start of hydraulic mining in the canyons above. With much of the Feather, and its tributaries the Yuba and Bear Rivers choked with mining debris, flooding became a serious problem. A series of floods during the 1860’s spread water and mud over much of the valley.

The enormous flood of winter 1861 - 62 spread devastation throughout the entire Sacramento Valley. Cattle died in great numbers, city business and residential districts were buried deep in water, and people were swept away to their deaths. During the flood, a large part of the tailings piling up in the Feather’s upper reaches were washed down to settle on the valley floodplains to depths of seven feet or more (Kelley 1989).

State engineer William Hammond Hall wrote in 1880 (Kelley 1989) that the deep river canyons in the mountains through which flowed the American, the Bear, and the Yuba were choked by immense deposits of mining debris which in some places were a hundred feet deep. For forty miles downstream from Oroville, with its cluster of large mining operations, the Feather's channel on the valley floor was also filled in. Altogether, some 684 million cubic yards of gravel had been mined on the Yuba, 100 million on the Feather, and 254 million on the Bear. All of this debris flowed into the lower Feather.

Dumping of hydraulic mining debris directly into the stream system virtually ceased in 1884 with the Sawyer Decision. The decision prohibited the direct dumping of debris into a river system, requiring catchments and dams to hold the debris.

The decline in hydraulic mining in the upper watershed occurred at the same time that gold dredging increased in the lower river basin. Large gold dredging operations occurred where the Feather, Yuba, and Bear Rivers entered the valley floor. Dredge tailings are still visible in large areas of the Oroville Wildlife Area on the Feather and near Parks Bar on the Yuba.

The scars of the hydraulic mines can still be seen around the town of Oroville. The famous Hendricks mine lies just north of Oroville Dam, and other mines in the North Fork were later buried under the waters of Lake Oroville.

Surveys done by U.S. Army Engineers showed depths of mining debris in 1880 and 1891. The depth of mining debris in the lower Yuba River decreased downstream from about 125 feet near Smartville, to 35 feet at the edge of the valley foothills, to about 20 feet near Marysville. Similar profiles were surveyed on the Bear that showed channel aggradation of about 150 feet about 12 miles from the mouth, to about 20 feet near the mouth.

Examination and mapping revealed that a total of 39,000 acres, or about 60 square miles of lower Feather River farmlands were buried under hydraulic mining debris (Kelley, 1989).

Surveys made on the Sacramento River near Sacramento in 1854 by the City Surveyor and again in 1880 by the State Engineer reveal a maximum filling of 30 feet and an average filling of 15.2 feet. Infilling in the Feather River was probably considerably more than this (Wildman 1981).

The channel degradation process began immediately after the end of the mining. In the steep canyons of the upper Feather, the deposits were washed downstream, leaving only a few high terrace remnants. In lower gradient valleys in the upper watershed, evidence of the massive dumping of mining debris is still evident in remnant terrace deposits flanking both sides of the valley. The terraces formed as the creeks and rivers incised the mining debris. Remnant terraces over one hundred feet above the present channels attest to the vast amount of debris that was flushed into the stream system.

The Yuba River joins the Feather about 20 miles above the confluence with the Sacramento River. The Yuba suffered the greatest impact from hydraulic mining because of the widespread deposits of gold - bearing gravel in its upper watershed.

In 1879 it was estimated that the canyons of the Yuba River contained over 25 million cubic yards of debris. Ten years later the estimate was about 6 million cubic yards, and by 1908, the deposit was nearly gone (Wildman 1981). While some of this gravel was removed by gravel operations, much of it was washed downstream to the mouth of the canyon where the Yuba enters the valley. This demonstrates that the main channel of the upper river system probably cleared a substantial amount of sediment relatively quickly, and returned to pre - mining stream geomorphology.

Over time, the finer mining debris moved as a “wave” slowly down the Feather, into the Sacramento River, past Sacramento, and into the Delta. Adler (1980, in Wildman 1981) studied degradation of hydraulic mine debris in the lower Yuba River. The rate of incision was greatest between 1906 and 1912 (1.1 foot per year) and decreased to 0.21 foot per year between 1912 and 1979. In many places the Yuba has recovered to its original streambed elevation, and has eroded below it in others.

Ninety percent of the debris still remains as a virtually permanent deposit. This is the cobbles, gravel, sand, silt, and clay deposited on the banks and floodplain. Between Oroville and Gridley, much of the river is incised into cobble and gravel mining debris. Between Gridley and Verona, the fine grained slickens in most places still constitute the lower part of the channel banks.

6.1.1.1 Impacts of Hydraulic Mining

Hydraulic mining in the study area started in 1853 in the mountain canyons east of Oroville. By 1895, when for the most part, hydraulic mining ceased, an incredible 1.2 billion tons of sediment had been washed into the Sacramento Valley. This sediment washed down the canyons, obliterating fish habitat, burying spawning gravel, and sterilizing the stream system. Much of the sediment washed out into the valley, depositing in the channel and driving much of the floodwater out into cities and over the valley farmland.

Mendell (1875, in WET 1991) records and describes this process:

"The….. physical condition of the Feather River is something wonderful, when we know that in 1849 it was the counterpart of the present Sacramento in all respects, namely, a succession of deep pools, separated from each other by shallow bars, the water being remarkably clear. At present day, all the pools along the Feather River have been filled up with washings from hydraulic mines, and changed into broad flats, covered with a sheet of water densely charged with sediment, and often barely 2 feet in depth, the only deep water being where the channel is contracted to 300 feet or less. An idea of the extent to which this filling has taken place can be appreciated when I state that the bottom of the river today is…. level with the tule - lands enclosed by the levees. These same pools in 1849 contained fully 30 feet of water where now there is scant 2 feet, and the bars have also been covered with sand so as no longer to be seen."

The present day Feather River is profoundly affected by the mining debris. Both the cobble banks and the slickens have increased bank stability. Between Oroville and Gridley, cobbles and coarse gravel constitute most of the banks, slowing the bank erosion process. Between Honcut Creek and the mouth, the meandering process has slowed or practically ceased, and the river is wide, shallow, with low sinuosity and a sand bed. Most of the reach is mapped as glides or long pools, with very little mesohabitat variability.

As a result of the hydraulic mining, the Feather River has changed character in the following ways:

- The river flows on a topographic high, as shown in Figure 6.1-1 (USGS 1982), caused by deposition of hydraulic mining debris, with flood basins to the west and east generally lower than the stream thalweg.

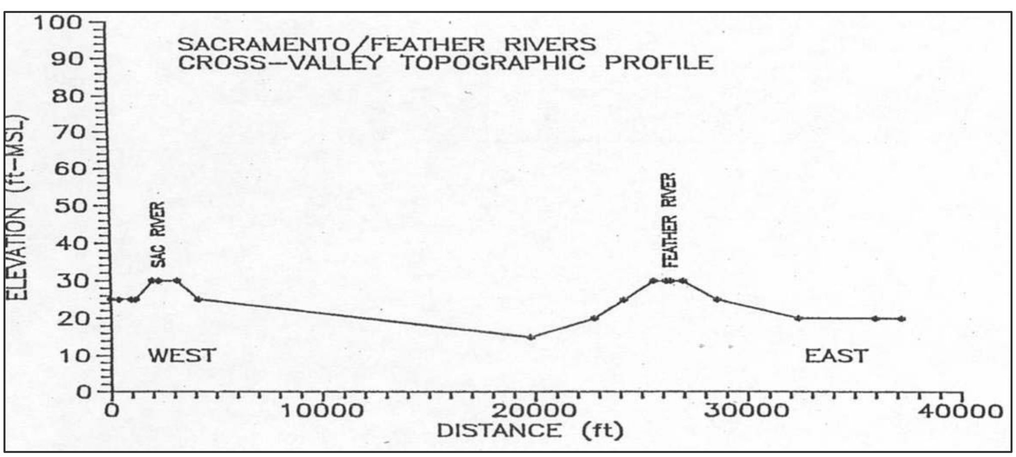

Figure 6.1-1. Cross - Valley Topographic Profile of Sacramento and Feather Rivers .

- Bank erosion is less. Stable clay and cobble banks increase bank stability and reduce bank erosion. Less bank erosion means impacts on meander rates, riparian succession, and sediment in the stream.

- The river has become entrenched. Cross - section analyses by the USGS (1972) shows that the channel thalweg has been scoured down as much as 6 feet, and the cross - sectional area has increased as much as 250% between 1909 and 1970.

- Meander rates have been reduced. Meandering is the primary source of stream mesohabitat diversity. Meandering is primarily responsible for the creation of oxbow lakes, multiple channels, side channels, islands, point bars, large woody debris, creation of riffle and pool habitat, and other features. The amount of these habitat types has been reduced over time.

- Gravel recruitment for salmon spawning riffles is less. Bank erosion of silt - gravel composite banks is one of the main sources of gravel for salmon spawning riffles. Bank erosion has been reduced for the following reasons. First, banks in the upper reach have become less erosion prone because of the coarse dredge tailings. Second, the lower reach is more stable because it is incised in slickens. The original silt - gravel banks still remain buried under hydraulic mining debris.

6.1.2 Dredging and Gravel Mining

After hydraulic mining decreased, following an injunction in 1884 and regulation in 1893, the Feather River began to redevelop equilibrium between streamflow, channel shape, and sediment transport. This trend was interrupted by dredge mining operations between 1905 and 1952, mostly in the Oroville Wildlife Area, and on the lower Yuba River.

Dredging consists of mining gravel deposits. First, a large pond is constructed in the gravel. A floating dredge is brought in that processes the gravel using buckets and conveyor belts. The dredge works its way across the floodplain by mining the gold - bearing gravel on one side of the pond and depositing the tailings in windrows on the other side. Dredging affects the river by disrupting the floodplain, moving the river channel, and discharging sediment to the river. Dredging does not change the amount of sediment, but it disrupts the layering, changes the surface topography, and moves the coarse cobbly bottom material to the top of the tailing pile.

Much has been written regarding the effect of gravel mining on stream morphology. Only a short description of these effects is given here.

Gravel mining first and foremost removes bed material from the stream bed. This affects the amount of gravel in the river and the amount available for transport. Gravel mining changes the depth, width, gradient, bedload, stream velocities, grain size distribution, and other hydraulic parameters.

Gravel mining pits located in the channel capture bedload, thereby stopping gravel replenishment on riffles below. Pits change the river gradient, typically causing bed erosion both upstream and downstream. Pits constructed off - channel are sometimes "captured" by the stream. This occurs mostly during floods, and results in changes in location of the stream bed, gradient, bed material, and habitat.

Instream gravel mining appears to have affected the Feather River mostly in an area between River Miles 56 and 64. Much of this activity has been offstream, including mining the floodplain and dredger tailings, and excavating pits.

Inspection of aerial photographs in this area suggests that some channel migration has occurred as a result of the mining. This has occurred because of accidental pit capture and stream diversion.

Gravel mining activity is still occurring today. However, it appears that the activity has been isolated from the main channel by levees, and no mining appears to be presently occurring in the active stream channel.

6.3 VOLCANIC ERUPTIONS

The upper portion of the North fork watershed including Warner and Summit creeks heads in Lassen Volcanic National Park on the slopes of Mt. Lassen. Mt Lassen is classified as an active volcano that last erupted in 1914-17. An eruption similar to the previous eruption could produce a volcanic mudflow into the upper reaches of the watershed that would be a continuing source of sediment. Most sediment produced in this portion of the watershed would be trapped by Lake Almanor.

6.4 AGRICULTURE

Agriculture is practiced on private lands throughout the watershed but is concentrated on valley land. Flat valley land contains deeper, more productive alluvial soils that are easier to cultivate and irrigate. Most irrigation diversion is for hay and pasture production. Sierra Valley, in the upper Middle Fork watershed, has large areas cultivated seasonally during the last 100 years.

Alfalfa, winter wheat, oat, hay, and other forage types are the major crops grown. Within the Sacramento Valley, rice and fruit - nut orchards are the principal agricultural land uses along the Feather River

6.5 TIMBER HARVESTING

The North and Middle Fork Feather River watersheds provide favorable conditions for timber production. The area has considerable climatic and biologic variety resulting in a productive and extensive forest. The timber industry grew from a few sawmills in the 1850s to a major industry in the watershed but has declined significantly since the late 1980s. Timber harvesting occurs on both public and private land.

The U.S. Forest Service has managed the public's timber resources since its establishment in 1910. The Plumas National Forest has jurisdiction over a total of 1,828 square miles with 1,606 square miles in the study area. Plumas National Forest includes 53 percent of the North Fork Feather River watershed and 44 percent of the Middle Fork Feather River watershed. The PNF historic average for timber sold per year is 190 million board feet. In the last few years, less timber has been sold because of cuts in congressional funding and changing environmental management policies. Small portions of Lassen National Forest and Tahoe National Forest are also contained within the watershed.

Private timber harvesting is a significant land use in the watershed. The Collins Pine Company has access to a large block of private timberlands. For a number of years, annual production from the Collins' Almanor Forest has nearly equaled timber production of the national forest (DWR 1988).

6.6 GRAZING

Montane meadows and large valleys provide favorable range for livestock grazing and production. Grasses grow abundantly during the spring and near streams during the entire summer.

Horse, sheep, and cattle grazing began during the gold rush years. "The late 1800s and early 1900s saw intensive sheep grazing on the upland areas and high meadows, while intensive cattle grazing was occurring in the large meadows" (USFS 1989, in DWR 1994). Many of the valley and streamside meadows are privately owned and are used for year - long livestock grazing.

The Plumas National Forest provides summer range for livestock from June to mid October using grazing permits. As of 1986, about 314,500 acres (27 percent) of the total 1,168,517 forest acres were classified as suitable for grazing activity. Of this available grazing land, about 71 percent was managed under a continuous grazing system, 27 percent was managed with a deferred system (grazing was deferred until plants reached seed maturity), and just 2 percent was managed with a rest - rotation system. During 1981, approximately 7,500 cattle and 1,400 sheep grazed on land in the Plumas National Forest (USFS 1986, in DWR 1994). Similar figures are not available for private land and other national forest land.

6.7 RECREATION

For local economies, revenues from recreational activities have begun to rival those of other land use activities. The Feather River watershed offers mountains, lakes and streams. Recreational activities include fishing, hunting, hiking, bike riding, horseback riding, camping, nature photography and study, swimming, boating and water skiing, gold panning and dredging, off - road vehicle and snowmobile use, and cross - country skiing. There are many recreational facilities, both public and private. Recreation in Plumas National Forest has generally increased since the 1950s. Recreation visitor days were 2.3 million in 1982, which grew 12 percent to 2.6 million by 1992 (USFS 1994, in DWR 1994). The USFS projects that recreation demand will increase at the current population growth rate in the region, reaching 4.6 million recreation visitor days by 2030 (USFS 1986, in DWR 1994).

Lake recreation is available at numerous lakes, the most significant of which are Lake Almanor and Lake Oroville. Camping, boating, and fishing are the primary recreational pursuits.

Fishing, boating and bird hunting are also important recreational opportunities along the lower Feather River.

6.8 DAMS AND HYDROELECTRIC DEVELOPMENT

Many small reservoirs, and some bigger ones, such as Lake Almanor, have been built in the upper watershed. Most of these facilities trap and prevent sediment from moving downstream. The dams in the watershed are listed in the hydrology section.

Combie Reservoir was constructed on the Bear River in 1928, primarily for debris storage and water supply. The surface area of the reservoir has been reduced by deposits extending half the length of the reservoir. Also located on the Bear are Camp Far West (1963) and Rollins (1964) reservoirs.

Bullards Bar dam was constructed in 1924 on the Yuba River for debris storage, water supply, and power. In 1969, New Bullards Bar was constructed for power, water supply, and recreation, inundating the old dam and reservoir.

Englebright Dam on the Yuba River was constructed in 1941 with federal funds to be used solely as a debris dam. Very little of this space was actually used for debris so the current uses are for power generation, water supply, and recreation. The reservoirs essentially halted the downstream movement of gravel from areas above. Consequently, channel scouring commenced below the dams.

Rock Creek, Cresta, and Almanor reservoirs on the North Fork, Miocene on the West Branch, Ponderosa on the South Fork and Lake Oroville have affected sediment transport on the lower Feather River. These Dams have affected the study reach geomorphology by reducing the amount of sediment. Cumulatively these dams have a trap efficiency of over 97 percent. Only very fine sediment is discharged to the stream below. All of the gravel and most of the sand is stopped by the dams, resulting in the loss of gravel recruitment to salmon spawning riffles in the downstream river reaches. Lack of recruitment has caused some of the riffles to become armored by cobbles and boulders. Honcut Creek is the only tributary providing sediment in the Oroville to Yuba City reach of the river.

The North Fork Feather River is extensively developed for hydroelectric power. About 720 megawatts are generated by Pacific Gas and Electric (Table 6.8-1) along the reach from Lake Almanor to Lake Oroville. The North Fork is advantageous for hydroelectric generation because of steep gradients, a large reservoir located high in the watershed, abundant snowfall, and high annual discharge.

Table 6.8-1. Hydroelectric Generating Plants on the Feather River above Lake Oroville.

HYDROELECTRIC GENERATING PLANTS	YEAR OPERATION BEGAN	FLOW AT NORMAL OPERATING CAPACITY (cfs)	NORMAL OPERATING CAPACITY (megawatts)
Hamilton Branch	1921	200	4.8
Butt Valley	1958	1,620	40.0
Caribou No. 1	1921	1,114	75.0
Caribou No. 2	1958	1,464	120.0
Belden	1969	2,410	125.0
Rock Creek	1950	2,880	112.0
Bucks Creek	1928	340	57.5
Cresta	1949	3,510	70.0
Poe	1958	3,700	120.0

Big Bend	1909	*	*
* Big Bend generating plant was inundated by Lake Oroville in 1968.			

Water storage has attenuated and reduced the frequency of channel - forming flows. High flows still occur during exceptional flood years, but because of the lack of sediment, the high flows that do occur scour the channel, causing widening and deepening. During most years, channel–forming flows do not occur in the Lower Feather River.

PG&E regulates releases from Lake Almanor on the North Fork throughout the year. Downstream of Lake Almanor a series of impoundments divert streamflow through tunnels and penstocks to hydroelectric generators. The major hydropower storage reservoirs from upstream to downstream include Mountain Meadows Reservoir, Lake Almanor, Butt Valley Reservoir, Rock Creek and Cresta Reservoirs, and Bucks Lake. The table above lists the PG&E powerhouses on the North Fork.

DWR has Antelope Lake, Frenchman Lake and Lake Davis but none of these have any hydroelectric development.

Because one of the primary functions of Oroville Dam is flood management it is expected that the effect of Oroville Dam on the magnitude of flood flows is dramatic. The average of the peaks of seven major pre - dam flood events was 190,000 cfs. The average of eight post - dam peaks through winter 1995 - 96 is about 74,000 cfs. Only one event, a February 1986 peak of 150,400 cfs approached the historic pre - dam high flows.

6.9 LEVEES

Levees have been built along most of the Feather River between Oroville and Verona. The width between the confining levees varies dramatically. In some places, the width is about the same as the stream channel. In other places, several miles of floodplain exist between the levees. Levee locations are shown in Figure 6.9-1 and are included in the Oroville Facilities Relicensing GIS database.

Levees are generally built for flood control and reclamation. The levees confine the flood flows, controlling the width, depth, gradient, and velocity. Levees tend to increase the sediment carrying capacity of the stream.

Levees reduce the interaction between a stream and its floodplain. Where levees are directly on the banks of the river, no interaction occurs. Levees set back from the river allow some interaction, including flooding, groundwater recharge, and sediment deposition. Many riparian species depend on this periodic flooding in their life cycle.

The construction of levees and training walls for flood control and reclamation began shortly after gold rush in 1849. The first levees were built by a few individuals to protect their own private property. In the spring of 1867, a seven mile long levee was completed on the Feather River west bank near Nicolaus (Kelley 1989). A levee was also constructed across Gilsizer slough that same year, with the idea of protecting Yuba City from repeated flooding. Unfortunately, the levee washed out during the torrential floods of 1867, inundating much of the city.

On the east side of the river, Yuba County and the town of Marysville had been busy building levees around the city. Roads were constructed on elevated berms that served as levees, thus allowing public funds to be used for flood protection.

In 1868, the State Legislature passed the Green Act, allowing the creation of Sutter County's Levee District 1. A levee was soon built 7.5 miles along the west side of the river. Unfortunately, the levee was overtopped, raised, and overtopped again over the ensuing years.

It was not until March 1, 1917 that a single comprehensive plan of flood containment was instigated. The federal Flood Control Act of 1917 ensured U.S. Army Corps of Engineers participation in developing and building a flood control project for the Sacramento Valley. As part of this project, levees were built along most of the Feather River from Oroville to the mouth.

On the west bank the levee system begins about seven miles north of Gridley. On the east bank, the levee begins on the south side of Honcut Creek, a few miles south of Gridley. The Feather River levee system ties into levee systems of the Yuba, Bear, Sutter Bypass, and Sacramento Rivers.

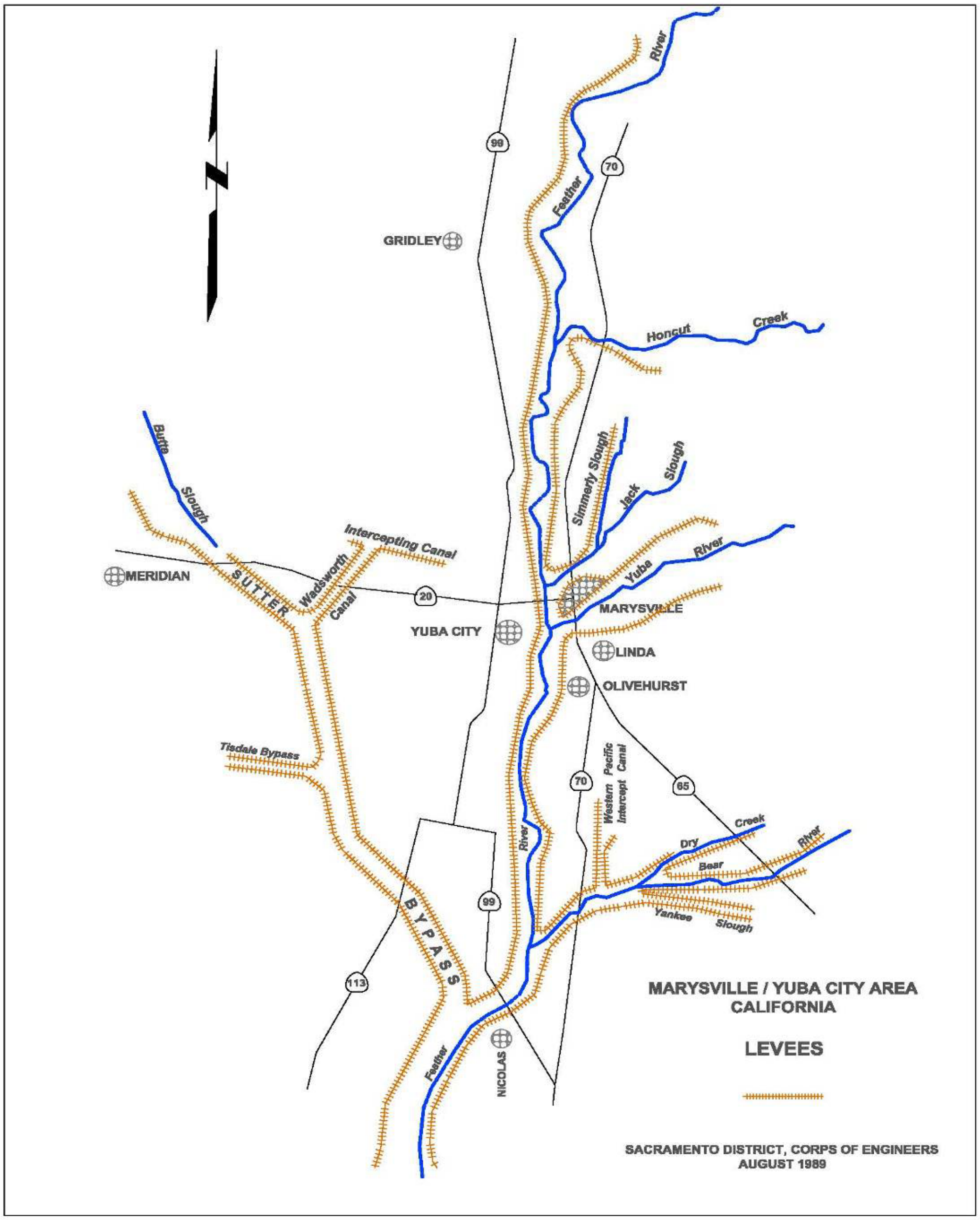

Figure 6.9-1. Levees along the lower part of the Feather River.

6.10 BANK PROTECTION

Bank protection occurs in places on the Feather. Bank protection consists of basalt quarry rock, cobbles, or concrete rubble. Minor bank protection occurs near Oroville, at the Highway 70 bridge, at the inlet and outlet weirs in the Oroville wildlife area, and at the Thermalito outfall. Riprap also occurs on the right bank near Gridley and the left bank below Honcut Creek.

Riprap below Yuba City is more common but not extensive. It is estimated that about 7 percent of the banks are riprapped, or about 20,000 feet. Location of riprap is on the Oroville Facilities Relicensing GIS database. Figure 6.10-1 shows the cumulative amount of riprap installed with time (adapted from Water Engineering and Technology)

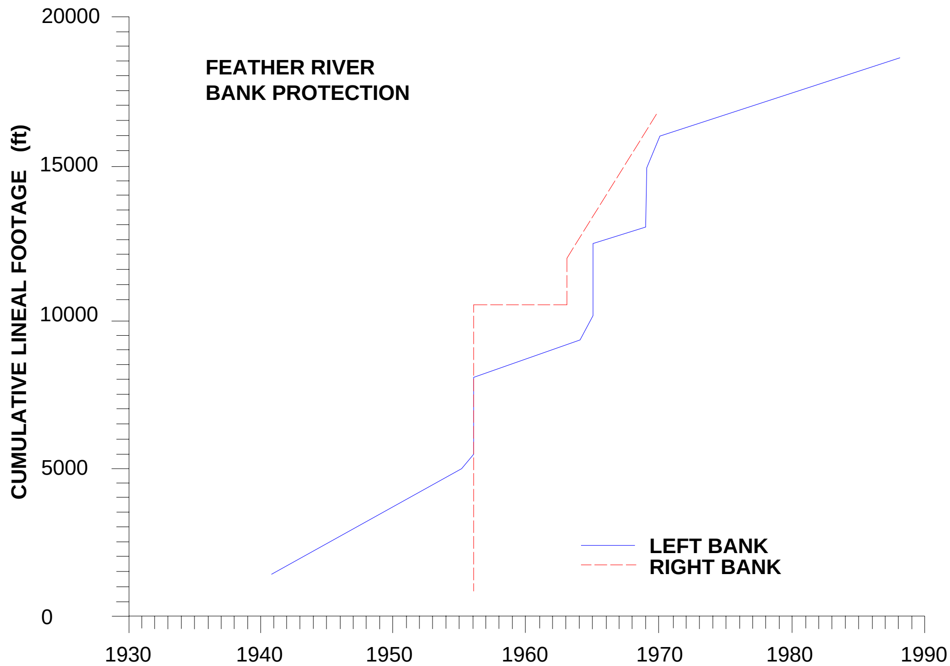

Figure 6.10-1. Rate of Bank Protection Emplacement.

6.11 HISTORIC FLOOD EVENTS

Records of flooding in the Sacramento Valley reach back to the 1850s. Most of the descriptions from this time are written observations since no gaging stations were installed until 1896 on the Sacramento River and 1903 on the Feather River. Descriptions of historic floods are from Robert Kelley's 1965 publication "The Feather River from Oroville to Marysville: 1848 - 1940" a document prepared for the Office of the Attorney General, Sacramento California.

Oroville Lake and Dam were completed in 1967, permanently altering the flood hydrology. Information on post - Oroville floods were derived from DWR, USGS, and USACE internet sites, DWR Bulletin 69 series, DWR Bulletin 199, and DWR Bulletin 161.

6.11.1 Pre - Oroville Dam Flood Events

Accounts of historic flood events begin with the flood of January 1850. Most of the Sacramento Valley was not populated and only a few ranchos were established on the valley floor. The small town of Sacramento had been newly established on the banks of the Sacramento River at the head of the Sacramento - San Joaquin Delta.

Heavy and intense rains began on January 7, 1850, and continued for several days. Two days later the river began to flood the downtown areas of Sacramento. Within a few hours the entire community was deep under rushing waters, and many of the newly constructed homes were washed away.

This flood began the cycle of levee building along the Sacramento River. One of the first levees was a three foot high structure designed to protect the downtown Sacramento area. The newly built levee failed in the flood of March 1852. Sacramento was again under water.

Farther upstream, the large influx of miners during the gold rush had resulted in a construction boom in the towns of Marysville and Yuba City on the banks of the Feather River. Much of the downtown area of Marysville flooded, resulting in the abandonment of much of the city near the river. In the countryside surrounding the two towns, crops were flooded and a large number of range animals were drowned.

An even larger event occurred in December of the same year, bigger than the two previous events. A familiar pattern of heavy rains, followed by rapidly rising streamflow, overtopped both streambanks and newly constructed levees. Thousands of cattle drowned in the lowlands as the lower part of the Sacramento Valley became a large inland sea.

Just a few months later, while the survivors of the 1852 floods were still cleaning up, the floods of March 1853 struck the valley. At Marysville, the Yuba River was almost three feet higher than previous floods. Boats were used to navigate in the downtown areas for the several weeks of receding floodwaters. In bottom lands, where farmers had settled earliest and agriculture was the most productive, almost every farmer suffered heavy losses.

In one of the more interesting coincidences, hydraulic mining was born on the upper part of the Feather River the same year. Hydraulic mining would continue for decades, dumping 1.2 billion cubic yards of debris into the stream system and exacerbating flooding in the valley below.

Flooding again occurred in March of 1861, and because both the Feather and Yuba were filling in with hydraulic mining debris, the water spread like a sheet between Marysville and Sacramento. Although as extensive as the flood of 1853, it was not nearly as catastrophic as the floods that occurred later in the year.

The double flooding that occurred during December 1861 and January 1862 was the most massive of all the valley floods. In addition to the water that covered the valley floor for more than a month, the receding floodwaters left a thick layer of sand, silt, and clay. The sediment, derived from mining activity in the Sierra Nevada to the east, destroyed vegetation and put many farms out of business.

Floods again visited the valley in 1866 and 1867. Will Green, living on the banks of the Sacramento River in Colusa, commented in 1866 that “without a doubt, more water passed down the valley than ever before since its settlement by whites in the same length of time”. The flood filled the entire Sutter basin. Similar floods occurred in February 1867, continuing into April and May. The summer months had no sooner dried the valley when the massive flood of December 1867 again turned it into a vast sheet of water. Colusa was an island, levees gave way in many areas. Yuba City flooded under 10 feet of water when a recently constructed levee gave way. Water levels were much higher than the flood of 1862, mostly because of infilling by hydraulic mining debris.

Cyclic flooding continued through the remainder of the 1860s, 70s, 80s, and 90s. Floods occurred in January 1868, December 1871, January 1872, January 1875, February 1878, March 1879, January 1881, December 1884, 1892, January 1896, and March 1899.

The 1875 flood did major damage to both Yuba City and Marysville. Levees failed in numerous places and water swept in from the north, west, and east, filling the encircled towns like fishbowls. Marysville became a vast dump for mining debris, filling streets, basements, stores, and homes. Whole ranches were abandoned after being buried in sand, silt, and clay.

The 1881 flood was as large, or larger than the 1861 - 62 flood, disrupting traffic, flooding Gridley, Biggs, and destroying railroad tracks and bridges near Honcut Creek. The Sutter Buttes again became an island.

Floods continued to occur on a periodic basis, but nothing quite as big as the March 1907 event that again rivaled the 1861 - 62 flood on the Feather River. Damage was enormous, with the towns of Oroville, Biggs, Marysville, Yuba City, Dredgerville, Colusa, and Sacramento being flooded. Levees failed throughout the valley. A stream gage had been installed in 1903 at Oroville, but the magnitude of flooding is not necessarily tied to the streamflow, since levee breaks and changes in channel capacity are also important constituents in the flooding equation. The Feather escaped its channel at Starr Bend. It was estimated that over 600,000 cfs were flowing into Suisun Bay.

A similar flood occurred in 1909, and a number of other floods occurred in the 1910s and 20s.

March 1928 was the first major flood to occur after the completion of the Sacramento River Flood Control Project. The Sacramento River performed remarkably well, but flooding still occurred from Oroville to Marysville on the Feather River.

A quote by W.T. Ellis regarding the 1928 flood said, "That the amount of water carried by the rivers were the greatest since 1862, which was the year of the great flood in the Sacramento River. The fact that the rivers have scoured deeply since the emergencies of 1907 and 1909 enabled them to carry the greater flow without exceeding the former high mark" (Kelley 1965). This clearly refers to the re - entrenchment of the Feather into the mining debris and a commensurate increase in channel capacity. Since mining had essentially stopped in 1884, the introduction of new material to the river had essentially stopped as well.

Feather River established a new high in 1937, being two feet above the 1928 high. A new levee built by the Corps of Engineers broke and the water went westward flooding some parts of East Biggs waist deep. The Cherokee Canal north of Biggs also broke, entirely surrounding the town with water. Live Oak was also flooded.

Storms also occurred in February 1940 with record flows, February 1942, January 1943, January 1953 before a major event occurred in December 1955.

The 1955 event began when more than 30 inches of rain fell in a few days on the Sacramento, Feather, and American river basins. The resultant flows were even higher than the record 1940 flows. The high flow again caused numerous levee failures, resulting in flooding of Yuba City and portions of other towns and agricultural land near Nicolaus. Loss of life was high with 38 people dying.

The December 1964 flood was the first to be affected by Oroville Dam. Oroville was under construction, with a core block dam and diversion tunnel completed. The dam and the storage it provided, curtailed the peak somewhat, reducing flooding downstream. Modifications to flood protection facilities between 1955 and 1964 prevented damage that might well have exceeded that caused by the 1955 flood. Over 375,000 acres of land flooded and several levees were breached.

6.11.2 Post -Oroville Dam Flood Events

The January 1970 flood was the first major flood occurring after completion of Lake Oroville. Much of the Sacramento Valley was declared a disaster area, as the Sacramento River swept over its banks. The Feather River only had 28,680 acres flooded, less than one - tenth of what flooded in 1964.

April 1974 was a significant flood year, flooding about 210,000 acres in the Sacramento Valley. This was followed by the floods of March 1983, with very high flows entering Lake Oroville. No major levee breaks occurred on the Feather River but flooding occurred in the Delta.

The February 1986 flood was one of the major events of the century. Water flowed over the Oroville Dam spillway at 150,000 cfs. Levees on the Yuba River broke, sending 24,000 people in Linda and Olivehurst fleeing from their homes. Flood waters eventually spread over 30 square miles, destroying homes, farms and businesses valued up to 100 million dollars in 1986. At the peak, 650,000 cfs were flowing past Sacramento in a levee system designed to carry 600,000 cfs. If not for the dams, DWR estimated that the flow would have been over a million cfs.

An average of 17 inches fell in the upper Feather River Basin in a five - day period from February 12 to the 17th. Bucks Lake, at elevation 5,750 feet, reported a 9 - day storm total of 49.6 inches (Bulletin 69 - 86, 1988) and inflow into Lake Oroville reached a high of 266,450 cfs on the 17th.

One of the most geographically extensive and costly floods of California's history occurred in January 1997. Forty-eight of the 58 California counties were declared a disaster area. The flood was caused by a combination of an unusually heavy snowpack of about eight feet and a warm sub - tropical rainstorm that brought unusually heavy precipitation.

California's dams and reservoirs helped prevent billions in damages. Lake Oroville accommodated 1.25 million acre - feet of runoff, an amount equivalent to more than one third of the lake's total capacity. Peak inflow exceeded 300,000 cfs and the outflow was 161,000 cfs. Flows were about 300,000 cfs below the confluence of the Yuba and Feather Rivers. The Corps of Engineers (USACE website) estimated a recurrence interval of about 190 years for this storm event.

This was the most costly storm in California's history, exceeding $5 billion. Nine people were killed and 120,000 evacuated in front of the encroaching flood waters. Levees failed throughout the State, with a total of over 600 levee damage sites and 60 breaches. A Feather River levee broke near Olivehurst and Linda, damaging many homes and businesses. Three hundred square miles of land were flooded. All told, 20,800 houses, 3,000 mobile homes, and 1,900 businesses in the State had been damaged or destroyed by the flood waters.

7.0 WATERSHED INSTABILITY, EROSION, AND SEDIMENT SOURCES

The upper Feather River watershed is producing high sediment yields. High sediment yields are caused by accelerated erosion. A U.S. Soil Conservation Service report, *East Branch North Fork Feather River Erosion Inventory Report* (1989), estimated that ninety percent of erosion in a 1,209 square mile study area was accelerated erosion. Accelerated erosion is a soil loss rate greater than natural geologic conditions and is caused by such human activities as road building, timber harvesting, overgrazing livestock, and agriculture. High sediment yield can reduce reservoir capacity, degrade water quality, and harm fish and wildlife. High sediment yields have significantly impaired storage capacity and hydroelectric operations in several reservoirs upstream of Lake Oroville on the North Fork Feather River.

A large amount of sediment is captured by reservoirs upstream of Lake Oroville with Lake Oroville capturing most of the remaining sediment from the upper watershed. This amount is estimated to be approximately 500 acre - feet per year. This in turn results in a sediment - starved river system below the dam. It is estimated that the trap efficiency of the reservoirs is above 97 percent or more. A portion of silt and clay is discharged to the Feather River below the dam, but no pebbles, gravel, or cobbles. High flows below the dam have scoured the streambed, resulting in coarsening and armoring of salmon spawning riffles as far downstream as Honcut Creek.

Past watershed instability, erosion, and sedimentation investigations have focused largely on tributaries of the North Fork with little attention to the Middle Fork watershed. This focus on the North Fork and its tributaries reflects concern over excessive sedimentation and increased maintenance effectively reducing the operating efficiency and life span of reservoirs and power plants. Landslides cause increased sedimentation and downstream cumulative effects. Erosion and down cutting of streams lowers groundwater levels and dewaters meadows. Reduced stream flow in the late summer and fall from dewatered meadows reduces hydropower generation capability. The dewatering of meadows has also resulted in a transformation from perennial grasses to dry land vegetation such as sagebrush.

7.1 WATERSHED INSTABILITY AND EROSION HAZARD

Landslides are a major source of sediment in the watershed. The western portion of the watershed is most sensitive to this hazard, particularly the canyons of the Feather River and canyons of Indian, Spanish, and Eureka creeks (USFS, 1986). Pre - historic landslides large enough to temporarily block the North Fork may have occurred. No basin - wide landslide investigation has been done in the Feather River drainage.

A 30,000 cubic yard landslide damaged two PG&E hydroelectric powerhouses and related equipment costing $40 million to repair (Sacramento Bee, February 26, 1985). The landslide occurred at the Caribou powerhouse and Belden Reservoir on the North Fork Feather River.

Numerous landslides occur along the Feather River and its major forks. Failures in this watershed are largely within volcanic and metamorphic rocks. The toes of a number of these landslides are now seasonally inundated by Lake Oroville. Landslide movements are mostly prehistoric. However, several failures indicate recent activity (DWR 1979). A large "dormant" landslide (approximately three square miles) is on the north slope of Bloomer Hill, directly above the North Fork in the Lake Oroville reservoir. The toe has recently been reactivated in places.

Rock units with a history of slope instability in the watershed are the metamorphic "greenstone" belt on Quincy road, serpentinite and talc schist, Tertiary non - marine gravel, and Tertiary pyroclastic rocks, especially those with high clay contents (USFS 1988, in DWR 1994).

The watershed within the Plumas National Forest has been mapped and ranked for erosion hazards by USFS for planning purposes. Department of Water Resources (1994) obtained the information from USFS and used it to prepare an Erosion Hazard Map. The map shows the potential for erosion hazard and landslide activity in the Plumas National Forest part of the watershed. Two land stability risk classifications used by Plumas National Forest, Low Risk and Moderate Risk, were combined as Class I, Low to Moderate Risk. Class I typically represents gentle to moderately steep (<60 percent) sloped lands with few signs of naturally caused slope instability. Class II, High Risk, represents steep slopes with visible signs of naturally caused slope instability. Class III, Extreme Risk, represents lands that are usually very steep (>75 percent) and show evidence of recent landslide occurrence. Risk areas were digitized from Plumas National Forest data using an Autocad computer program. The resources used by the USFS contractors to compile the original Risk Maps at 1:24,000 scale include: 1) slide feature maps from aerial photo interpretation; 2) slope maps, geologic maps, soils maps, aerial photos, and site specific landslide information from existing engineering geology reports, and; 3) personal observations of USFS personnel.

Streambank erosion information was obtained from a Soil Conservation Service report, *East Branch North Fork Feather River Erosion Inventory Report* (SCS 1989, in DWR 1994). The area covered by that report includes all of the East Branch and three other sub-watersheds of the North Fork Feather River. Streams, with sediment production of 600 tons per square mile or more, were highlighted.

The Instability and Erosion Hazard Map is only complete in Plumas National Forest for about 50 percent of the study area. Minimal data exist in parts in Lassen and Tahoe National Forests or on private land.

The greatest erosion effects occur on the East Branch of the North Fork Feather River. The deteriorating condition is evident with gully formation and channel down - cutting occurring on a large scale in the broad alluvial valleys in the upper part of the watershed.

Table 7.1-1 below presents sediment data from sub - watersheds within the East Branch watershed. These data were obtained from the Soil Conservation Service report *East Branch North Fork Feather River Erosion Inventory Report* (1989), written in cooperation with the Feather River Coordinated Resource Management Group.

Table 7.1-1. Sediment Yield to Rock Creek Reservoir.

Sub - watershed Number *	Sub - watershed Name	Tons per Square Mile
2	Above Antelope Lake	2,120
3	N.F. Feather River	1,760
9	Wolf - Round Valley	1,650
5	Upper Spanish - Rock	1,300
6	Lower Spanish	1,160
13	Last Chance	1,110
11	Hungary - Mid. Indian	1,110
7	Greenhorn	1,050
15	Red - Clover Dixie	830
8	Little Grizzly	770
4	Rush - Mill	760
10	Lights - Cooks	730
14	Squaw Queen	660
1	Chips - Yellow	610
2	Butt Valley Res.	0

* Sub - watersheds are ranked in descending order of sediment yield in tons per square mile. Sub - watershed numbers are keyed to ArcView GIS coverages.

7.2 LAKE OROVILLE INSTABILITY AND EROSION HAZARD

Numerous landslides exist along the banks of Lake Oroville. These are on ArcView GIS coverages of the Lake Oroville area and discussed in detail in the SP-G1 Report. The landslides occur in granitic and metamorphic rocks that form the hills and valleys of the westernmost portion of the Sierra Nevada. Many of the landslides continue into the depths of the reservoir. It is common for the motion to occur along joint and/or fracture planes, especially in the granitic rocks.

The landslides were mapped using aerial photography and then confirmed in the field. Field confirmation included boating up to each slide looking for scarps, rubble and debris, lobes at the base (low lake levels made this possible), any other signs of movement, and walking the boundaries if necessary. Some of the landslides were taken from previously completed DWR landslide maps. The type of landslide was determined and then classified as ancient, active or inactive (DWR 1979).

A translational – rotational slide is characterized by a cohesive slide mass and a failure plane that is deeper that a debris slide. The motion is linear for the translational portion and arcuate in the rotational portion. Generally these slides have rotational heads and translational bodies. A debris slide is unconsolidated rock, colluvium, and soil that has moved downslope along a relatively shallow failure plane. Debris slides form steep unvegetated scars in the head region and irregular hummocky deposits in the toe region. An earthflow is mass movement resulting from flow of saturated soil and debris in a semi-viscous, highly plastic state.

Active landslides display evidence of recent movement, such as fresh barren scarps, jackstrawed trees, displaced roads and stream channels, and clusters of large rocks in stream channels or lake shore. Vegetation on active landslides is typically sparse, with willow, grass, and brush predominant.

Inactive landslides have well developed and easily recognized slide topography. Bowl or spoon shaped depressed areas are bounded by steep crown and flanking slopes. Flat lobes and irregular hummocky topography are well defined. Depressed sags and ponds, water seeps, and water loving vegetation are common. Vegetation is generally a well established, mature forest stand but may vary in type and density from surrounding stable areas. Trees with bowed trunks occur. This feature may indicate that deep seated movement is presently occurring at slow rates. Inactive landslides define areas of past instability and indicate sensitivity to erosion and mass wasting.

Ancient landslides have indistinct boundaries and subdued landslide form. Crown and flanking slopes are rounded and ill defined. Sags and ponds are typically absent. These landslides usually are covered by well - established, mature stands of the same age class as the surrounding forest. The lack of well defined features and boundaries suggests that many hundreds—perhaps thousands—of years have passed since active movement occurred. Ancient landslides outline zones where deep soil and disturbed rock can be expected to be sensitive to management projects. Roads that cross both inactive and ancient landslide areas commonly have cut and fill slope failure problems associated with clay soils and high water tables.

The area of all the confirmed landslides mapped around Lake Oroville is approximately 3,996 acres. Of that 301 acres (8 percent) are active, 525 acres (13 percent) are inactive, and 3,196 acres (79 percent) are ancient landslides. Over 75,000 feet of shoreline is comprised of landslide material.

The majority of the active landslides are a result of reactivation of inactive or ancient landslides. There are also a number of small active landslides that are due to bank/toe failure at the edge of the reservoir, especially on the Middle Fork. These are likely caused by the repeated wave action along the shoreline under cutting already unstable areas.

The majority of the active, inactive, and ancient landslides (42 percent) are found in the arc complex rocks. The arc complex rocks contain 42 percent of the total landslide acreage (the majority of the active, inactive, and ancient landslides), metasedimentary rocks contain 20 percent, mélange contains 12 percent, Smartville ophiolite contains 12 percent, intrusive rocks contain 9 percent, and metavolcanic rocks contain 5 percent.

Soil erosion in the lake fluctuation zone is not a serious problem. Erosion typically ranges from a few feet to somewhat over 10 feet. The SP-G1 Report covers this subject in detail.

8.0 REFERENCES

Andrews, E. D. and J. M. Nankervis. 1995*. Effective Discharge and the Design of Channel Maintenance Flow for Gravel - Bed Rivers.* In: Natural and Anthropogenic Influences in Fluvial Morphology. American Geophysical Union. Geophysical Monograph 89.

Bilby, R. E. and J. W. Ward. 1989. *Changes in Characteristics and Function of Woody Debris with Increasing Size in Streams in Western Washington*. Transactions of the American Fisheries Society. 118. Pp. 368 - 378

BioAnalysts, Inc. 2000. *The Role of Large Woody Debris in Rocky Reach Reservoir.* Report prepared for FERC Project No. 2145. Public Utility District No. 1, Chelan County, Wenatchee, Washington. Boise, Idaho. 14 pp.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. D. Sedell. 1987. *Large Woody Debris in Forested Streams in the Pacific Northwest: Past, Present, and Future*. pp. 143 – 193. In: E. O. Salo and T. W. Cundy, eds. Streamside Management: Forestry and Fishery Interactions.

Braudick, C. A. and G. E. Grant. 2000. *When do Logs Move in Rivers?* Water Resources Research, 36 (2). Pp 571 – 583.

California Department of Fish and Game. 1997. *California Salmonid Stream Habitat Restoration Manual.*

California Department of Water Resources 1994. *North Fork and Middle Fork Feather River Watershed Report.* Northern District. 77pp.

California Department of Water Resources. 1994. *1993-1994 Lake Oroville Siltation Study*. Northern District.

California Department of Water Resources. May 1988. *California High Water 1985 - 86*. Bulletin 69 - 86.

California Department of Water Resources. March 1985. *California High Water 1983 - 84.* Bulletin 69 - 84.

California Department of Water Resources. 1983. *Monitoring Spawning Habitat, Feather River*. Northern District. 20pp.

California Department of Water Resources. 1982. *Feather River Spawning Gravel Baseline Study*. Northern District.

California Department of Water Resources. September 1980. *California Flood Management: An Evaluation of Flood Damage Prevention Programs*. Bulletin 199.

California Department of Water Resources 1979. *South Fork Trinity Watershed Erosion Investigation*. Northern District Report.

California Department of Water Resources. 1979. *The August 1, 1975 Oroville Earthquake Investigations*. 669pp.

California Department of Water Resources. May 1967. *Bank Erosion Investigations: Feather River at Nelson Bend.*

California Department of Water Resources. *Establishment of Feather River Channel Characteristics*, *1965 to1969*. Delta Branch.

California Department of Water Resources. August 1967. *California High Water 1965 - 66.* Bulletin 69 - 66. .

California Department of Water Resources. January 1965*. Flood! December 1964—January 1965*. Bulletin 161.

Creely, R.S. 1965. Geology of the Oroville Quadrangle, California. California Division of Mines and Geology. San Francisco. 86pp.

Curran, J. H. and E. E. Wohl. 2003. *Large Woody Debris and Flow Resistance in Step - Pool Channels, Cascade Range, Washington*. Geomorphology 51. 141 – 157.

Fischenich, J. C. and J. V. Morrow, Jr. 2000. *Streambank Habitat Enhancement with Large Woody Debris.* EMRRP Technical Notes Collection (ERDC TN - EMRRP - SR - 13). U.S. Army Engineer Research and Development Center. Vicksburg, Tennessee, 15 pp.

Goodwin. 1999. *Fluvial Classification: Neanderthal Necessity or Needless Normalcy.* Wildland Hydrology

Harwood, D. and E. Helley. 1987. *Late Cenozoic Tectonism of the Sacramento Valley, California.* U.S. Geological Survey Prof. Paper 1359. 46pp.

Hill, M. T. and, W. S. Platts, R. L. Beschta. 1991. *Ecological and Geomorphological Concepts for Instream and Out - of - Channel Flow Requirements.* Rivers. 210, Volume 2, Number 1.

Hyatt, T. L. and R. J. Naiman. 2001. *The Residence Time of Large Woody Debris in the Queets River, Washington, USA*. Ecological Applications 11 (1). 191 - 202

Kelley, R. 1989. *Battling the Inland Sea: Floods, Public Policy and the Sacramento Valley.* University of California Press. Berkeley, Los Angeles, London.

Kelley, R. 1965. *The Feather River From Oroville to Marysville: 1848 - 1940.* Prepared for the Office of the Attorney General State of California. Sacramento, CA.

Leicester, M. 2003. *Distribution, Species Composition, and Abundance of Trees and Large Woody Debris Adjacent to and within Gazos Creek*. San Jose State University. San Jose, California. 19 pp.

Manga, M. and J. W. Kirchner. 2000. *Stress Partitioning in Streams by Large Woody Debris.* Water Resources Research. V. 36 (8). Pp 2373 – 2379.

Murphy, M. L., J. Heifetz, S. W. Johnson, K. V. Koski, and J. F. Thedinga. 1986. *Effects of Clear - Cut Logging with and without Buffer Strips on Juvenile Salmonids in Alaskan Streams.* Canadian Journal of Fisheries and Aquatic Sciences. V. 43. Pp. 1521 - 1533

O'Connor Environmental, Inc. 2000. Garcia River Large Woody Debris Instream Monitoring. Report prepared for Mendocino County Resource Conservation District, Mendocino County, California. Healdsburg, California. 20 pp + app.

O'Connor, M. D. and R. R. Ziemer. 1989. *Coarse Woody Debris Ecology in a Second - Growth Sequoia Sempervirens Forest Stream.* Pp. 165 - 171. In: D. L. Abell, tech. coord. Proceedings of the California Riparian Systems Conference: Protection, Management, and Restoration for the 1990's. September 22 - 24, 1988, Davis, California. General Technical Report PSW – 110. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. Berkeley, California. 544 pp.

Richter B. D., J.V. Baumgartner, J. Powell, and D.P Braun. 1996. *A Method for Assessing Hydrologic Alteration within Ecosystems*. Conservation Biology. V.10. Pp.1163 - 1174.

Robison, E. G. 1988. *Large woody debris and channel morphology of undisturbed streams in southeast Alaska.* M.S. thesis. Oregon State University. Corvallis, Oregon. 136 pp.

Robison, E. G. and R. L. Beschta. 1990. *Characteristics of Coarse Woody Debris for Several Coastal Streams of Southeast Alaska, USA*. Canadian Journal of Fisheries and Aquatic Sciences. V. 47 (9). Pp. 1684 - 1693

Robison, E. G. and R. L. Beschta. 1990. *Coarse Woody Debris and Channel Morphology Interactions for Undisturbed Streams in Southeast Alaska, USA*. Earth Surface Processes and Landforms. V.15. Pp. 149 -156

Rosgen, D. L. and H. L. Silvey. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, CO. Printed Media Companies. Minneapolis, Minnesota.

Schweickert R. and D. Cowan. 1975. *Early Mesozoic Tectonic Evolution of the Western Sierra Nevada, California.* Geol. Soc. Am. Bull. Vol. 86. Pp. 1329-1336.

Sedell, J. R. and K. J. Luchessa. 1982. *Using the Historical Record as an Aid to Salmon Habitat Enhancement.* pp. 210 - 223. in: N. B. Armentrout, ed. *Acquisition and Utilization of Aquatic Habitat Inventory Information*. American Fisheries Society, Western Division. Portland, Oregon.

Sedell, J. R., P. A. Bisson, F. J. Swanson, and S. V. Gregory. 1988. *What We Know about Large Trees that Fall into Streams and Rivers.* pp. 47 - 81. In: C. Maser, R. F. Trappe, and J. F. Franklin. *From the Forest to the Sea: a Story of Fallen Trees.* General Technical Report PNW - GTR – 229. USDA Forest Service. Pacific Northwest Research Station. Seattle, Washington.

The Nature Conservancy. 1997*. Indicators of Hydrologic Alteration, User's Manual*. The Nature Conservancy and Smythe Scientific Software. 53pp.

United States Army Corps of Engineers. January 1971. *Report on the January 1970 Floods, Sacramento River Basin, California*. Sacramento District.

U. S. Army Corps of Engineers. 1907 to 1911. California Debris Commission Surveys and Maps Showing Topography and Cross-sections.

U.S. Geological Survey. 1989. *Late Cenozoic Stratigraphy of the Feather and Yuba Rivers Area, California, with a Section on Soil Development in Mixed Alluvium at Honcut Creek.* Bulletin 1590. 66 pp. with tables.

U.S. Geological Survey. 1987*. Late Cenozoic Tectonism of the Sacramento Valley, California*. USGS Professional Paper 1359. 46 pp.

U.S. Geological Survey. 1985. *Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley and Northern Sierra Foothills, California.* MF-1790.

U.S. Geological Survey. 1978. *Sediment Transport in the Feather River, Lake Oroville to Yuba City, California*.

U.S. Geological Survey. 1972. *Determination of Channel Capacity of the Feather River between Oroville and Honcut Creek, Butte County, California*. Menlo Park, California. 54pp.

Water Engineering and Technology. 1990. *Geomorphic Analysis and Bank Protection Alternatives Report for Sacramento River (RM 78-194) and Feather River (RM 0-28).* Fort Collins, Colorado. 278 pp.

Water Engineering and Technology. 1991. *Geomorphic Analysis and Bank Protection Alternatives Report for Sacramento River, Feather River, Yuba River, Bear River, and American River.* Fort Collins, Colorado. 327 pp.

Wildman, Nancy A. 1981. *Episodic Removal of Hydraulic-Mining Debris, Yuba and Bear River Basins, California.* Masters Thesis. Department of Earth Resources. Colorado State University, Fort Collins, Colorado. 107pp.

William Lettis and Associates. 2002. *Phase II Fault and Seismic Hazards Investigation – North of Delta Offstream Storage Investigation*. Report prepared for the Department of Water Resources.

Wong, I.G. 1992. *Earthquake Activity in the Sacramento Valley, California and its Implications to Active Geologic Structures and Contemporary Tectonic Stresses.* In Chevren, and Edmundson, eds. *Structural Geology of the Sacramento Basin.* American Association of Petroleum Geologists. Pacific Section. P. 5-14

APPENDIX A – ROSGEN LEVEL II ANALYSIS

Wolman Results

Cross-section	COE Rivermile	DWR Rivermile	Width/Depth Ratio	Entrenchment Ratio	Water Surface Elev. (ft)	Sinuosity	Slope	Shape	Substrate	Stream Type
67	66.3	67	15.54	1.4	142		0.2273%	Shallow/ Wide		C?
66	65.3	66	57.63	2.3	130		0.1052%	Shallow/ Wide	gravel and cobble	C4
65	64.4	65	83.14	1.2	125		0.0948%	Shallow/ Wide	gravel, sand and bedrock	C4c-
64*	64	64.6	51.19	2.1	123	1.46	0.0947%	Shallow/ Wide	cobble	C3c-
63	63	63.6	60.51	1.3	118		0.0000%	Shallow/ Wide	cobble and gravel	F3
62	62	62.6	64.74	20.9	118		0.0758%	Shallow/ Wide	cobble and gravel	F3
61	61	61.5	91.83	1.1	114		0.1705%	Shallow/ Wide	cobble and gravel	F3
60	60	60.25	78.10	1.2	105		0.0568%	Shallow/ Wide	boulders to sand	F2
59	59	59.35	111.70	1.1	102		0.0758%	Shallow/ Wide	gravel and cobble	F4
58	58	58.4	52.48	1.1	98		0.0189%	Shallow/ Wide	cobble and sand	F3
57	57	57.5	90.39	2.5	97		0.0947%	Shallow/ Wide	cobble	F3
56	56	56.4	239.05	1.1	92		0.1326%	Shallow/ Wide	cobble and gravel	F3
55	55	55.3	143.22	1.1	85		0.0947%	Shallow/ Wide	cobble	F3
54	54	54.5	94.17	1.1	80		0.0379%	Shallow/ Wide	cobble and gravel	F3
53	53	53.45	73.19	1.7	78		0.0947%	Shallow/ Wide	gravel and sand	F4
52	52	52.4	63.15	2.9	73		0.0379%	Shallow/ Wide	cobble	F3
51	51	51.3	71.37	1.4	71		0.0758%	Shallow/ Wide	gravel	F4
50	50	50.2	60.66	1.4	67		0.0000%	Shallow/ Wide	gravel	F4
49	49	49.05	48.67	5.7	67		0.0379%	Shallow/ Wide	gravel and sand	F4
48	48	47.8	87.86	1.2	65		0.0947%	Shallow/ Wide	cobble and sand	F3
47	47	46.7	90.87	1.1	60		0.0568%	Shallow/ Wide	50% gravel/ 50% sand	F4/5

Cross-section	COE Rivermile	DWR Rivermile	Width/Depth Ratio	Entrenchment Ratio	Water Surface Elev. (ft)	Sinuosity	Slope	Shape	Substrate	Stream Type
46	46	45.8	180.13	1.1	57		0.0569%	Shallow/ Wide	cobble and gravel	F3
45	45	44.7	106.47	1.6	54		0.0569%	Shallow/ Wide	sand and gravel	F5
44	44	43.75	57.88	1.3	51		0.0189%	Shallow/ Wide	gravel w/ boulder riprap	F4
43	43	42.8	44.94	1.3	50		0.0379%	Shallow/ Wide	gravel, sm. cobble and sand	F4
42	42	41.8	119.02	1.1	48		0.0190%	Shallow/ Wide	gravel and sand	F4
41	41	40.85	65.70	1.2	47		0.0190%	Shallow/ Wide	gravel and sand	F4
40	40	39.75	55.36	3.7	46		0.0000%	Shallow/ Wide	gravel and sand	F4
39	39	38.7	46.22	1.1	46		0.0000%	Shallow/ Wide	unknow n	F4
38	38	37.8	98.56	1.1	46		0.0190%	Shallow/ Wide	gravel and sand	F4
37	37	36.75	40.00	13.6	45		0.1137%	Shallow/ Wide	gravel and sand	F4
36	36	35.6	139.66	1.0	39		0.0199%	Shallow/ Wide	sand, gravel and silt	F5
35	35	34.8	117.15	1.2	38		0.0568%	Shallow/ Wide	sand, gravel and silt	F5
34	34	34.3	19.70	27.9	35		0.0000%	Shallow/ Wide	sand, gravel and silt	F5
33	33	33.6	59.18	1.1	35		0.0000%	Shallow/ Wide	sand, gravel and silt	F5
32	32	32.4	21.33	1.3	35		0.0000%	Shallow/ Wide	sand, gravel and silt	F5
31	31	31.4	37.05	7.2	35		0.0379%	Shallow/ Wide	sand, gravel and silt	F5
30	30	30.6	27.96	10.1	33		0.0189%	Shallow/ Wide	sand, gravel and silt	F5
29	29	29.6	62.65	1.1	32		0.0379%	Shallow/ Wide	sand, gravel and silt	F5
28	28	28.6	38.50	0.9	30		0.0000%	Shallow/ Wide	sand, gravel and silt	F5
27	27	27.5	237.30	1.0	30		0.0000%	Shallow/ Wide	sand, gravel	F5

Cross-section	COE Rivermile	DWR Rivermile	Width/Depth Ratio	Entrenchment Ratio	Water Surface Elev. (ft)	Sinuosity	Slope	Shape	Substrate	Stream Type
									and silt	
27**		27**	98.84	1.0	30		0.0000%	Shallow/ Wide	sand, gravel and silt	F5
26		26	80.90	2.7	30		0.0000%	Shallow/ Wide	sand, gravel and silt	F5
25		25	49.18	1.2	30		0.0311%	Shallow/ Wide	bedrock	F1
24		24	64.57	1.1	28		0.0183%	Shallow/ Wide	sand	F5
23		23	131.12	1.0	27		0.0192%	Shallow/ Wide	sand	F5
22		22	95.34	1.1	26		0.0000%	Shallow/ Wide	sand	F5
21		21	90.61	1.4	26		0.0185%	Shallow/ Wide	sand	F5
20		20	162.19	1.1	25		0.0000%	Shallow/ Wide	sand	F5
19		19	110.96	1.1	25		0.0000%	Shallow/ Wide	sand	F5
18		18	87.31	2.6	25		0.0199%	Shallow/ Wide	sand	F5
17		17	72.70	1.1	24		0.0000%	Shallow/ Wide	sand	F5
16		16	95.60	1.4	24		0.0213%	Shallow/ Wide	sand	F5
15		15	122.92	1.3	23	1.27	0.0000%	Shallow/ Wide	sand	F5
14		14	52.93	4.4	23		0.0223%	Shallow/ Wide	sand	C5
13		13	110.45	3.4	22		0.0000%	Shallow/ Wide	sand	C5
12		12	156.33	1.1	22		0.0380%	Shallow/ Wide	sand	C5
11		11	127.30	5.2	20		0.0226%	Shallow/ Wide	sand	C5
10		10	119.76	2.9	19		0.0245%	Shallow/ Wide	sand	C5
9		9	108.06	#VALUE!	18		0.0376%	Shallow/ Wide	sand	C5
8		8	95.94	1.1	16		0.0000%	Shallow/ Wide	sand	C5
7		7	82.92	16.9	16		0.0000%	Shallow/ Wide	sand	C5
6		6	118.50	11.2	16		0.0187%	Shallow/ Wide	sand	C5
5		5	96.58	13.4	15		0.0000%	Shallow/ Wide	sand	C5
4		4	99.73	1.4	15		0.0193%	Shallow/ Wide	sand	C5
3		3	101.04	1.3	14		0.0000%	Shallow/ Wide	sand	C5
2		2	103.91	13.0	14		0.0198%	Shallow/ Wide	sand	C5
1		1	90.53	14.4	13		0.0188%	Shallow/ Wide	sand	C5
0		0	115.512	16.5	12	1.04		Shallow/ Wide	sand	C5

*Started using different set of rivermiles at this point

Cross-section	COE Rivermile	DWR Rivermile	Width/Depth Ratio	Entrenchment Ratio	Water Surface Elev. (ft)	Sinuosity	Slope	Shape	Substrate	Stream Type
**Started using first set of rivermiles again -- the second set used was more accrate, but incomlpete										
Note: The last section is classified as a "C" because the presence of the levees results in an increase of the entrenchment ratio.										
Note: From rivermile 7 to 0 the distance between levees was used to determine flood prone area widths -- there are no elevation contours for the channel in this stretch.										
Note: Anomalous entrenchment ratio values will be marked in a shape file.										

APPENDIX B – ANALYSIS OF LARGE WOODY DEBRIS

TableB-1. Lower Feather River Large Woody Debris, Number and Location by River Mile

Mile	Location					Total
	Backwater	Left Bank	MidChannel	Right Bank	SideChannel	
0	-	30	8	45	-	83
1	-	3	6	27	-	26
2	-	28	9	37	-	74
3	-	24	3	41	-	68
4	-	13	2	43	-	58
5	-	21	4	31	-	56
6	-	12	1	51	-	52
7	-	21	1	54	-	47
8	-	25	-	32	-	45
9	-	9	5	3	-	17
10	-	40	3	15	-	38
11	-	38	2	28	2	45
12	-	6	4	14	-	21
13	-	22	2	15	-	26
14	-	5	-	10	-	10
15	-	6	3	9	-	18
16	-	21	2	57	-	80
17	-	4	2	20	-	26
18	-	6	4	12	-	22
19	-	16	3	11	-	30
20	-	9	9	19	-	37

Mile	Location					Total
	Backwater	Left Bank	MidChannel	Right Bank	SideChannel	
21	-	22	-	33	-	55
22	-	18	4	28	-	50
23	-	18	12	14	-	44
24	-	17	10	6	-	33
25	-	12	-	17	12	41
26	-	7	3	38	26	67
27	-	24	4	16	3	47
28	-	46	26	17	2	91
29	-	155	42	111	-	308
30	-	138	81	123	-	342
31	-	95	42	160	-	297
32	-	158	89	121	-	368
33	-	134	57	140	-	331
34	-	156	208	209	-	573
35	-	27	60	37	-	124
36	-	34	34	20	-	88
37	-	59	50	45	-	148
38	-	42	25	63	-	136
39	-	52	35	34	-	121
40	-	41	29	31	-	101
41	-	54	78	59	-	191
42	-	148	132	79	-	359
43	-	93	75	69	-	237

Mile	Location					Total
	Backwater	Left Bank	MidChannel	Right Bank	SideChannel	
44	4	29	43	28	11	117
45	6	72	21	26	-	124
46	2	119	19	24	-	163
47	3	118	42	36	24	223
48	3	51	18	19	23	114
49	7	53	13	16	55	144
50	1	73	26	40	-	127
51	-	43	17	30	-	76
52	-	23	17	27	-	58
53	-	37	13	28	-	69
54	-	12	7	16	-	34
55	-	23	10	21	3	54
56	-	8	1	30	-	42
57	-	27	6	14	-	47
58	22	49	3	54	-	128
59	1	7	1	9	-	18
60	-	6	4	6	-	16
61	-	7	6	6	-	19
62	-	10	8	7	-	25
63	-	8	10	20	-	38
64	6	27	3	17	-	53
65	-	3	1	24	-	28
66	-	6	6	19	-	31

Mile	Location					Total
	Backwater	Left Bank	MidChannel	Right Bank	SideChannel	
Total	55	2720	1464	2554	161	6954
Mean	0.82	40.60	21.85	38.12	2.41	103.79

Table B-2. Large Woody Debris on the Lower Feather River Number of LWD per River Reach

Reach	# of Miles in Reach	Total LWD	Mean LWD/Mile	Low	High
FR below Yuba River	28	1345	48.1	15	83
FR from Yuba River to Honcut Creek	16	3815	238.5	88	573
FR from Honcut Creek to Afterbay Outlet	15	1566	104.4	35	223
FR from Afterbay Outlet to Fish Barrier Dam	8	228	28.5	16	53

Table B-3. Large Woody Debris on the Lower Feather River Number and Percentage of LWD per River Habitat

Habitat Type	#	Acres	% Acres	#LWD	%LWD	#/Acre
Backwater	57	83.6	2.7	308	4.4	3.67
Boulder Run	1	0.7	0.2	0	0	0
Glide	75	2203.6	73.3	4800	69.0	2.18
Pool	79	551.6	18.2	1259	18.1	2.28
Riffle	83	102.0	3.4	426	6.1	4.17
Run	7	66.2	2.2	161	2.3	2.42
Total	302	3007.7	100	6954	99.9	

Appendix C Mesohabitat Survey Table
Oroville to Honcut Creek

Appendix C Mesohabitat Survey Table Oroville to Honcut Creek									
REACH NUMBER	HABITAT TYPE	SUBSTRATE	DEPTH FEET	WIDTH METERS	PERIMETER METERS	AREA METERS 2	COVER CODE	COMMENTS	ACREAGE
0	Backwater		0.0	0.0	2.5	0.2	0		0.00
94a	Riffle	Cobble	2.0	19.0	206.1	1682.8	0		0.42
1a	Pool	Bedrock	0.0	131.0	538.9	8531.5	0	Observed from distance	0.00
1c	Pool	Bedrock	0.0	81.0	1965.8	57549.9	0	Observed from distance	0.00
1b	Glide	Bedrock	0.0	44.0	400.6	5968.3	0	Observed from distance	0.00
1	Pool	Cobble	0.0	52.0	1995.4	38526.6	0		9.52
2	Riffle	Cobble	1.0	15.0	145.7	985.6	0		0.24
3	Backwater	Cobble	3.0	6.0	168.3	416.6	0		0.10
4	Pool	Cobble	5.0	22.0	235.9	2112.7	0		0.52
5	Riffle	Cobble	1.0	23.0	242.8	1253.6	0		0.31
6	Glide	Cobble	5.0	29.0	162.7	1222.8	0		0.30
7	Glide	Cobble	3.0	36.0	337.5	5081.8	0		1.26
8	Pool	Cobble	4.0	41.0	549.1	8650.6	0		2.14
9	Riffle	Cobble	1.0	4.0	101.1	170.3	0		0.04
11	Glide	Cobble	2.0	14.0	65.4	303.4	0		0.08
12	Pool	Cobble	4.0	28.0	194.8	1466.5	0		0.36
13	Riffle	Cobble	1.0	46.0	320.5	4277.7	0		1.06
14	Riffle	Cobble	2.0	22.0	94.6	376.1	0		0.09
15	Pool	Cobble	4.0	33.0	455.3	5611.9	0		1.39
16	Glide	Cobble	4.0	15.0	239.3	2181.1	0		0.54
17	Glide	Cobble	6.0	35.0	443.0	6569.0	0		1.62
18	Riffle	Cobble	2.0	19.0	126.3	753.3	0		0.19
19	Glide	Cobble	3.0	13.0	108.3	524.2	0		0.13
20	Glide	Cobble	7.0	41.0	475.6	7492.4	0		1.85
21	Riffle	Cobble	1.0	20.0	110.9	383.5	0		0.10
22	Glide	Cobble	2.0	9.0	59.7	178.3	0		0.04
23	Pool	Cobble	4.0	9.0	218.0	872.8	0		0.22
24	Pool	Cobble	13.0	12.0	176.3	955.1	0		0.24
25	Riffle	Cobble	1.0	7.0	111.6	319.8	0		0.08
26	Riffle	Cobble	2.0	65.0	466.7	11384.7	0		2.81
27	Backwater		7.0	15.0	213.6	1402.5	0		0.35
28	Glide	Gravel and Cobble	5.0	60.0	1683.4	44065.9	1		10.89
29	Backwater		6.0	34.0	963.0	14819.2	0		3.66
30	Pool	Gravel and Cobble	6.0	21.0	665.7	6793.6	0	substrate assumed	1.68
31	Riffle	Cobble and Gravel	2.0	53.0	578.1	11642.7	0		2.88
32	Backwater		4.0	18.0	151.5	1147.4	0		0.28
33	Glide	Gravel	6.0	86.0	396.0	7461.9	1		1.84
34	Pool	Gravel, Sand, and Bedrock	9.0	79.0	3561.5	128671.9	0		31.80
35	Backwater		5.0	45.0	470.9	8081.9	0		2.00
36	Glide	Cobble	9.0	84.0	482.6	12849.3	1		3.18
37	Pool	Gravel, Sand, and Bedrock	8.0	96.0	870.1	30422.8	0		7.52
38	Riffle	Gravel and Boulder	1.0	59.0	288.7	4944.4	0		1.22
39	Pool	Gravel	2.0	53.0	301.1	4367.8	0		1.08
40	Backwater		2.0	9.0	148.4	571.8	0		0.14
41	Glide	Cobble	4.0	47.0	442.1	8419.0	0		2.08
42	Riffle	Cobble	1.0	35.0	262.7	2952.5	0		0.73
43	Backwater		4.0	38.0	447.5	4953.6	0		1.22
44	Pool	Cobble and Gravel	5.0	70.0	491.9	7864.4	0		1.94

Appendix C Mesohabitat Survey Table Oroville to Honcut Creek									
REACH NUMBER	HABITAT TYPE	SUBSTRATE	DEPTH FEET	WIDTH METERS	PERIMETER METERS	AREA METERS 2	COVER CODE	COMMENTS	ACREAGE
45	Glide	Cobble and Gravel	2.0	81.0	408.4	8451.9	1		2.09
46	Riffle	Cobble and Gravel	2.0	48.0	409.9	6706.5	1		1.66
47	Glide	Cobble and Gravel	4.0	43.0	309.8	3415.0	0		0.84
48	Backwater		3.0	20.0	165.7	1207.2	0		0.30
49	Pool	Cobble and Gravel	13.0	83.0	1628.5	60468.2	1	submergent vegetation	14.94
50	Backwater		9.0	23.0	675.0	6885.4	0		1.70
51	Backwater		6.0	21.0	228.2	2086.0	0		0.52
52	Riffle	Gravel, Cobble, Boulder	2.0	33.0	205.9	1824.2	2		0.45
53	Glide	Gravel and Cobble	2.0	29.0	286.4	3283.9	0		0.81
54	Pool	Cobble and Gravel	7.0	100.0	2278.3	103801.1	0		25.65
55	Backwater		3.0	22.0	264.1	2492.8	0		0.62
56	Boulder Run	Boulders and Cobbles	5.0	58.0	239.8	2792.3	3		0.69
57	Pool	Cobble and Gravel	13.0	100.0	2969.9	138437.4	1		34.21
58	Backwater		6.0	39.0	873.7	15997.9	0		3.95
59	Glide	Cobble and Sand	3.0	82.0	714.1	20429.9	1		5.05
60	Riffle	Cobble and Gravel	1.0	28.0	568.3	7209.8	0		1.78
61	Pool	Gravel and Cobble	6.0	90.0	1009.1	28162.3	1	Submergent Vegetation	6.96
62	Glide	Gravell, Cobble, and Boul	3.0	47.0	742.7	8840.6	1		2.19
63	Riffle	Gravel, Cobble, and Bould	1.0	18.0	99.9	605.5	1		0.15
64	Riffle	Gravel and Cobble	2.0	26.0	377.8	3318.2	0		0.82
65	Run	Cobble and Gravel	3.0	35.0	283.3	3113.0	0		0.77
66	Backwater		4.0	31.0	271.1	3100.4	0		0.77
67	Pool	Cobble	4.0	47.0	973.0	19549.3	1		4.83
68	Riffle	Cobble	1.0	11.0	333.3	1123.1	1		0.28
69	Riffle	Cobble	1.0	37.0	495.5	5596.5	1		1.38
70	Backwater		2.0	50.0	382.8	4502.6	0		1.11
71	Glide	Cobble	2.0	13.0	111.7	479.1	1		0.12
72	Glide	Cobble	3.0	20.0	269.6	2204.1	1		0.55
73	Backwater		8.0	25.0	357.8	2828.5	0		0.70
74	Pool	Silt	13.0	35.0	318.3	4284.4	0		1.06
75	Run	Fine Gravel	4.0	41.0	981.3	17915.2	0		4.43
76	Backwater		2.0	17.0	136.8	823.7	0		0.20
77	Pool	Fine Gravel	3.0	12.0	147.0	764.3	0		0.19
78	Pool	Boulders to Sand	6.0	54.0	1219.3	25899.1	0		6.40
79	Backwater		6.0	19.0	323.2	2568.0	0		0.64
80	Riffle	Cobble	0.0	0.0	40.4	49.8	0		0.01
81	Glide	Cobble	2.0	15.0	350.5	2217.4	1		0.55
82	Pool	Cobble	9.0	13.0	87.5	390.0	1		0.10
83	Glide	Cobble	7.0	20.0	294.6	1988.2	1		0.49

Appendix C Mesohabitat Survey Table Oroville to Honcut Creek									
REACH NUMBER	HABITAT TYPE	SUBSTRATE	DEPTH FEET	WIDTH METERS	PERIMETER METERS	AREA METERS 2	COVER CODE	COMMENTS	ACREAGE
84	Riffle	Cobble	2.0	22.0	366.5	2912.1	0		0.72
85	Backwater	Cobble and Silt	6.0	37.0	295.1	4037.3	0		1.00
86	Pool	Silt and Cobble	9.0	58.0	1445.3	37447.3	1	Submergent Vegetation	9.25
87	Backwater		4.0	31.0	398.5	5257.8	0		1.30
88	Backwater	Gravel and Cobble	5.0	48.0	1177.3	24912.4	0		6.16
89	Riffle	Cobble and Gravel	2.0	29.0	157.2	1148.7	0		0.28
90	Glide	Cobble and Gravel	4.0	26.0	767.8	8554.0	1		2.11
91	Pool	Cobble and Gravel	3.0	11.0	106.7	465.3	0		0.12
92	Pool	Gravel and Cobble	6.0	87.0	2744.4	104132.6	0		25.73
93	Glide	Gravel	2.0	14.0	445.1	2652.5	1		0.66
94	Glide	Gravel	5.0	75.0	1210.7	27470.2	1		6.79
95	Pool	Gravel	9.0	50.0	381.7	5954.8	0		1.47
96	Riffle	Cobble	2.0	134.0	323.2	3373.3	1		0.83
97	Glide	Gravel	3.0	145.0	535.5	16901.4	1		4.18
98	Riffle	Cobble	2.0	45.0	376.2	5448.2	0		1.35
99	Riffle	Cobble	2.0	77.0	311.5	6160.9	0		1.52
100	Glide	Cobble and Gravel	4.0	47.0	743.6	14464.8	0	substrate assumed	3.57
101	Pool	Cobble and Gravel	6.0	14.0	110.1	432.3	0	substrate assumed	0.11
102	Glide	Cobble and Gravel	4.0	39.0	447.7	6107.1	1		1.51
103	Pool	Gravel	8.0	49.0	337.6	5818.6	2		1.44
104	Glide	Cobble	4.0	55.0	278.2	2747.9	0		0.68
105	Riffle	Cobble and Gravel	2.0	29.0	221.1	1852.8	0		0.46
106	Pool	Cobble and Sand	5.0	53.0	1674.9	38905.1	2		9.61
107	Backwater	Cobble and Sand	7.0	20.0	348.9	2880.0	0	substrate assumed	0.71
108	Pool	Cobble and Sand	6.0	60.0	934.6	20520.8	0	substrate assumed	5.07
109	Backwater	Cobble and Sand	5.0	10.0	122.6	532.4	0	substrate assumed	0.13
110	Glide	Cobble and Sand	8.0	67.0	295.6	3645.1	0	substrate assumed	0.90
111	Riffle	Cobble and Sand	3.0	98.0	297.5	2888.6	0	substrate assumed	0.71
112	Pool	Cobble and Sand	4.0	53.0	1172.3	26387.3	0	substrate assumed	6.52
113	Glide	Cobble and Gravel	3.0	63.0	589.4	14597.0	2		3.61
114	Riffle	Gravel and Cobble	3.0	38.0	104.0	520.8	1		0.13
115	Glide	Cobble and Gravel	3.0	38.0	288.9	3710.6	2		0.92
116	Glide	Cobble and Gravel	5.0	53.0	206.7	2667.1	0	substrate assumed	0.66
117	Riffle	Gravel and Cobble	5.0	41.0	157.9	1275.0	0	substrate assumed	0.32
118	Backwater	Cobble and Gravel	3.0	13.0	111.4	569.4	0		0.14

Appendix C Mesohabitat Survey Table Oroville to Honcut Creek									
REACH NUMBER	HABITAT TYPE	SUBSTRATE	DEPTH FEET	WIDTH METERS	PERIMETER METERS	AREA METERS 2	COVER CODE	COMMENTS	ACREAGE
119	Riffle	Gravel and Cobble	2.0	53.0	176.4	1881.1	0		0.47
120	Backwater	Cobble and Gravel	1.0	19.0	155.8	1128.0	0		0.28
121	Glide	Cobble and Gravel	5.0	54.0	1681.8	33225.0	0		8.21
122	Pool	Gravel and Cobble	2.0	11.0	178.1	767.1	0		0.19
123	Pool	Cobble and Gravel	14.0	54.0	419.8	8095.0	0		2.00
124	Riffle	Cobble	2.0	64.0	349.1	5600.6	0		1.38
125	Pool	Cobble	5.0	80.0	505.4	14246.9	0		3.52
126	Glide	Cobble	4.0	98.0	1523.7	53042.6	0		13.11
127	Pool	Gravel	2.0	17.0	219.5	1646.1	1		0.41
128	Backwater	Gravel	3.0	18.0	199.5	1296.3	0		0.32
129	Riffle	Cobble and Gravel	2.0	18.0	124.7	781.9	0		0.19
130	Glide	Cobble and Gravel	3.0	29.0	713.4	8032.6	0		1.99
131	Riffle	Cobble and Gravel	2.0	60.0	407.2	7212.2	0		1.78
132	Riffle	Cobble and Gravel	2.0	58.0	175.1	1425.1	0		0.35
133	Glide	Cobble and Gravel	4.0	37.0	662.2	9850.6	0		2.43
134	Backwater	Cobble and Gravel	1.0	5.0	87.3	210.8	0		0.05
135	Glide	Cobble and Gravel	3.0	45.0	724.8	14229.3	0		3.52
136	Riffle	Cobble and Gravel	2.0	39.0	478.0	6614.3	0		1.63
137	Glide	Cobble	4.0	66.0	1205.8	31364.5	0		7.75
138	Backwater	Cobble	2.0	12.0	198.2	974.8	0		0.24
139	Riffle	Cobble	2.0	32.0	248.5	2766.0	0		0.68
140	Riffle	Cobble	2.0	23.0	232.2	2267.5	0		0.56
141	Backwater	Cobble	3.0	25.0	150.9	1205.8	0		0.30
142	Pool	Cobble and Gravel	7.0	64.0	814.0	16822.5	0		4.16
143	Backwater	Cobble and Gravel	4.0	13.0	104.4	539.7	0		0.13
144	Glide	Cobble and Gravel	5.0	44.0	569.8	9748.3	0		2.41
145	Riffle	Gravel and Cobble	2.0	51.0	312.8	3371.2	0		0.83
146	Pool	Cobble	5.0	38.0	855.1	13135.0	2		3.25
147	Riffle	Cobble	2.0	55.0	382.8	4955.3	0		1.22
148	Pool	Cobble	3.0	38.0	866.1	14419.5	0	substrate assumed	3.56
149	Glide	Cobble	3.0	41.0	394.2	5293.4	2		1.31
150	Glide	Cobble	3.0	58.0	219.6	3207.2	0	substrate assumed	0.79
151	Riffle	Cobble	2.0	48.0	255.8	3560.8	0	substrate assumed	0.88
152	Riffle	Cobble	2.0	44.0	347.0	3507.0	2		0.87
153	Backwater	Cobble	5.0	51.0	254.6	3796.8	0		0.94
154	Riffle	Cobble	2.0	78.0	977.8	22860.1	0		5.65
155	Glide	Cobble	4.0	62.0	800.2	19744.2	1		4.88
156	Pool	Cobble	4.0	60.0	316.0	5979.6	1		1.48
157	Glide	Cobble	4.0	98.0	2472.6	93685.7	0		23.15

Appendix C Mesohabitat Survey Table Oroville to Honcut Creek									
REACH NUMBER	**HABITAT TYPE**	**SUBSTRATE**	**DEPTH FEET**	**WIDTH METERS**	**PERIMETER METERS**	**AREA METERS 2**	**COVER CODE**	**COMMENTS**	**ACREAGE**
158	Riffle	Cobble and Gravel	2.0	39.0	160.9	969.6	1		0.24
159	Backwater	Cobble	2.0	35.0	533.6	6997.4	0		1.73
160	Backwater		3.0	17.0	427.9	3263.7	0		0.81
161	Riffle	Cobble and Gravel	2.0	46.0	929.2	14106.1	1		3.49
162	Glide	Cobble and Gravel	3.0	17.0	178.7	1325.4	0		0.33
163	Glide	Cobble and Gravel	2.0	22.0	316.3	3144.0	0		0.78
164	Glide	Cobble and Gravel	5.0	36.0	269.6	2770.5	0		0.69
165	Pool	Gravel, Cobble, Silt	8.0	46.0	1192.3	23814.7	2		5.89
166	Riffle	Cobble	2.0	66.0	293.8	4461.1	0		1.10
167	Glide	Cobble and Gravel	1.0	75.0	342.4	7067.2	2		1.75
168	Pool	Cobble and Gravel	7.0	84.0	2470.4	91204.3	1		22.54
169	Backwater	Cobble and Gravel	1.0	13.0	94.4	332.7	0		0.08
170	Backwater	Cobble and Gravel	4.0	47.0	578.9	8830.0	0		2.18
171	Riffle	Cobble and Gravel	2.0	78.0	289.7	3000.2	0		0.74
172	Glide	Cobble	4.0	58.0	453.5	9851.4	2		2.43
173	Pool	Cobble	6.0	72.0	599.3	16009.4	0		3.96
174	Glide	Cobble	3.0	64.0	383.2	7227.8	2		1.79
175	Riffle	Cobble and Gravel	2.0	52.0	406.7	4601.3	1		1.14
176	Pool	Gravel and Sand	6.0	81.0	1320.7	43490.7	2		10.75
177	Backwater	Gravel and Sand	5.0	36.0	599.8	8248.4	0		2.04
178	Riffle	Cobble	2.0	60.0	314.4	2693.4	0		0.67
179	Glide	Cobble	4.0	45.0	851.2	15091.1	1		3.73
180	Pool	Cobble	6.0	81.0	1150.5	37913.7	1		9.37
181	Backwater	Cobble	1.0	14.0	253.9	1626.5	0		0.40
182	Riffle	Cobble	2.0	36.0	211.6	2402.9	0		0.59
183	Glide	Cobble	4.0	60.0	715.5	16972.9	1		4.19
184	Riffle	Gravel and Cobble	2.0	43.0	158.9	1216.6	0		0.30
185	Run	Cobble	5.0	39.0	617.9	9414.7	0		2.33
186	Backwater	Cobble	1.0	6.0	139.6	388.2	0		0.10
187	Pool	Cobble	6.0	63.0	507.2	11846.6	0		2.93
188	Backwater	Cobble	1.0	17.0	304.8	1944.1	0		0.48
189	Glide	Cobble	5.0	49.0	729.3	14844.5	0		3.67
190	Pool	Cobble	6.0	76.0	1079.1	30919.9	0		7.64
191	Backwater	Cobble	3.0	49.0	430.3	7355.9	0		1.82
192	Backwater		4.0	17.0	165.4	1037.2	0		0.26
193	Riffle	Gravel	2.0	95.0	363.4	5047.3	2		1.25
194	Pool	Cobble an Fine Gravel	6.0	71.0	729.0	17624.4	0		4.36
195	Riffle	Fine Gravel	2.0	91.0	414.5	4925.1	1		1.22
196	Pool	Gravel	7.0	101.0	8012.1	351234.1	2		86.79
197	Backwater	Gravel	1.0	8.0	117.7	362.9	0		0.09
198	Backwater	Gravel	5.0	42.0	482.3	4728.1	0		1.17
199	Glide	Cobble	3.0	63.0	289.5	4376.0	0		1.08
200	Riffle	Cobble	2.0	23.0	147.9	755.0	0		0.19

Appendix C Mesohabitat Survey Table Oroville to Honcut Creek									
REACH NUMBER	HABITAT TYPE	SUBSTRATE	DEPTH FEET	WIDTH METERS	PERIMETER METERS	AREA METERS 2	COVER CODE	COMMENTS	ACREAGE
201	Glide	Cobble	2.0	31.0	419.1	5209.4	0		1.29
202	Riffle	Cobble	1.0	11.0	333.9	1480.2	0		0.37
203	Pool	Cobble	7.0	45.0	986.7	15689.7	0		3.88
204	Glide	Cobble	4.0	46.0	412.8	6163.8	1		1.52
205	Riffle	Cobble	2.0	39.0	238.0	3189.9	0		0.79
206	Glide	Cobble	5.0	33.0	192.1	1854.5	0		0.46
207	Glide	Cobble	5.0	44.0	551.0	9899.6	0		2.45
208	Pool	Gravel and Sand	8.0	45.0	833.8	16326.5	0		4.03
209	Backwater	Gravel and Sand	5.0	14.0	555.8	3471.8	0		0.86
210	Backwater	Gravel and Sand	1.0	34.0	556.2	7489.1	0		1.85
211	Glide	Gravel and Sand	5.0	89.0	888.1	29811.3	1		7.37
212	Riffle	Cobble and Gravel	3.0	43.0	2066.1	29157.5	2		7.21
213	Pool	Gravel and Sand	5.0	48.0	1243.0	25063.6	1		6.19
214	Glide	Gravel and Cobble	3.0	40.0	402.9	5524.7	0		1.37
215	Glide	cobble	2.0	64.0	419.7	8404.1	0		2.08
216	Backwater	Cobble	4.0	15.0	280.8	1760.9	0		0.44
217	Pool	Cobble and Sand	7.0	102.0	1665.6	61018.1	2		15.08
218	Backwater	Cobble	2.0	35.0	235.3	2470.3	0		0.61
219	Riffle	Gravel and Sand	2.0	34.0	232.9	3120.1	0		0.77
220	Pool	Gravel and Sand	4.0	33.0	483.9	6100.3	2		1.51
221	Riffle	Gravel and Cobble	2.0	89.0	356.8	5519.8	0		1.36
222	Pool	Cobble and Sand	10.0	68.0	1653.4	48465.0	2		11.98
223	Riffle	Gravel and Cobble	2.0	46.0	368.8	3018.1	1		0.75
224	Pool	Gravel and Sand 50/50%	8.0	43.0	444.9	7955.8	2		1.97
225	Riffle	Cobble and Gravel	2.0	66.0	257.7	2429.0	2		0.60
226	Riffle	Cobble and Gravel	2.0	28.0	131.9	964.6	0	substrate assumed	0.24
227	Pool	Cobble and Gravel	9.0	46.0	564.2	10340.1	0	substrate assumed	2.56
228	Pool	Gravel and Sand 50/50%	6.0	81.0	3309.5	119348.3	2		29.49
229	Backwater	Cobble and Gravel	7.0	24.0	333.3	3168.0	0		0.78
230	Backwater	Gravel and Sand	6.0	38.0	430.4	5815.2	0		1.44
231	Riffle	Cobble and Gravel	2.0	60.0	580.7	7698.1	1		1.90
232	Glide	Cobble and Gravel	5.0	70.0	695.8	13265.2	1		3.28
233	Pool	cobble and gravel	6.0	86.0	829.8	21782.2	2		5.38
234	Backwater		2.0	22.0	156.5	1070.8	0		0.27
235	Riffle	Cobble and Gravel	2.0	36.0	310.5	3532.3	1		0.87

Appendix C Mesohabitat Survey Table Oroville to Honcut Creek									
REACH NUMBER	**HABITAT TYPE**	**SUBSTRATE**	**DEPTH FEET**	**WIDTH METERS**	**PERIMETER METERS**	**AREA METERS 2**	**COVER CODE**	**COMMENTS**	**ACREAGE**
236	Backwater	Cobble and Gravel	4.0	27.0	246.7	1959.6	0		0.48
237	Glide	Gravel and Cobble	4.0	72.0	1414.3	43490.0	2		10.75
238	Pool	Gravel and Sand	6.0	94.0	795.3	28774.9	1		7.11
239	Glide	Gravel and Sand	6.0	102.0	1063.9	37451.6	0		9.25
240	Riffle	Cobble and Gravel	2.0	72.0	385.8	6969.8	0		1.72
241	Glide	Gravel, Cobble, Sand	3.0	84.0	293.5	2948.2	0		0.73
242	Riffle	Cobble and Sand	1.0	85.0	222.0	1735.3	0		0.43
243	Glide	Gravel, Cobble, Sand	3.0	81.0	368.0	7584.8	0		1.87
244	Riffle	Cobble and Gravel	2.0	99.0	655.7	11461.4	2		2.83
245	Glide	Cobble and Sand	3.0	66.0	434.1	6489.6	0		1.60
246	Pool	Sand and Gravel	5.0	90.0	654.4	15282.6	0		3.78
247	Pool	Sand and Gravel	6.0	28.0	300.9	2422.1	0		0.60

Appendix C continued. Mesohabitat Survey Table Honcut Creek to Verona								
ID	AREA	PERIMETER	HABITAT TYPE	SUBSTRATE	COVER CODE	DEPTH FEET	WIDTH FEET	COMMENTS
248	8016.865	377.498	Riffle	gravel and sand	2	2.0	245.0	
249	4801.249	596.635	Backwater		1	3.0	96.0	
252	4168.783	732.509	Pool	sand and gravel	3	5.5	39.0	
251	1796.921	212.752	Pool	sand	0	5.0	61.0	
250	36566.460	1945.163	Glide	gravel and sand	0	5.0	244.0	
253	8197.473	738.506	Riffle	gravel and sm. cobble	2	3.0	104.0	
254	5536.266	306.309	Pool	gravel and sand	3	7.5	215.0	
256	577.202	137.923	Riffle	sm. cobble and gravel	0	2.0	180.0	
255	38972.169	1324.113	Glide	gravel and sand	3	5.0	305.0	
257	14385.993	735.762	Riffle	sm. cobble	0	2.0	172.0	
258	5852.246	478.540	Pool	gravel	2	7.5	120.0	
259	14835.367	888.989	Run	gravel with boulder ripra	1	4.0	156.0	
260	7970.081	510.324	Glide	gravel and sand	0	3.0	303.0	
261	15420.850	523.884	Riffle	gravel and sand	2	2.0	416.0	
263	7828.060	587.474	Backwater		0	10.0	196.0	
264	3212.768	388.012	Pool	bedrock	1	10.0	61.0	
265	2865.002	213.191	Riffle	sm. cobble and gravel	1	2.0	154.0	
266	6777.481	535.435	Pool	gravel and sand	2	9.0	94.0	
267	3621.502	258.846	Pool	gravel and sand	3	9.0	117.0	
262	139769.927	4828.216	Glide	gravel and sand	3	6.0	255.0	
269	5046.372	703.334	Pool	gravel and sand	3	7.5	50.0	
268	12873.227	739.971	Riffle	gravel and silt/clay	0	2.0	210.0	
271	2875.960	306.049	Riffle	gravel and sand	0	2.0	258.0	
272	3526.832	592.597	Pool	gravel and sand	2	9.0	41.0	
270	82301.995	2930.342	Glide	gravel and sand	3	5.0	238.0	
273	38326.028	1498.616	Pool	gravel and silt	1	11.0	254.0	
274	5304.698	426.425	Riffle	sand and silt	3	2.0	168.0	
275	218679.323	6110.765	Glide	gravel and sand	3	7.0	306.0	
276	31862.422	1377.678	Pool	unknown	1	12.0	158.0	
277	91170.017	2906.873	Backwater	unknown	0	9.0	222.0	Diverson
278	14051.311	597.484	Pool	unknown	2	14.0	195.0	
279	2296.493	437.949	Riffle	sm. cobble	1	1.0	122.0	
280	18314.874	843.741	Run	gravel	2	5.0	273.0	
282	17507.704	1527.362	Riffle	gravel and sand	1	2.0	144.0	
281	23943.223	976.232	Glide	sand and silt	2	6.0	225.0	
284	1343.493	157.059	Riffle	gravel and sm. cobble	1	2.0	201.0	
283	31956.510	1238.245	Run	gravel and	2	6.0	214.0	

				sand				
286	841.392	175.315	Backwater	gravel and sand	0	3.0	41.0	
285	14419.030	721.215	Pool	sand and silt	2	9.5	186.0	
288	4315.112	548.874	Pool	sand and silt	2	9.5	63.0	
287	172382.612	5336.066	Run	gravel and sand	3	7.0	221.0	
290	1426.577	250.532	Riffle	sand and gravel	1	0.0	0.0	mostly sand
291	1848.975	309.393	Riffle	gravel and sand	0	2.0	82.0	
293	43072.624	1228.668	Pool	sand	2	20.0	506.0	
294	32694.427	1873.449	Riffle	bedrock and lg. cobble	2	3.0	331.0	
295	65857.087	1573.821	Pool	sm. cobble	1	7.0	343.0	
297	14144.769	845.779	Backwater	sand and silt	3	38.0	119.0	
298	4686.717	378.357	Pool	sand	3	11.0	99.0	
300	23035.781	1265.110	Pool	silt/clay	1	10.0	139.0	
292	17122.100	899.801	Pool	sand	3	8.0	132.0	
289	2126540.644	48219.460	Glide	sand, gravel, silt	3	7.0	420.0	pool depth is at least 10
296	5449570.989	89349.708	Glide	sand	3	6.0	414.0	
299	26064.599	1128.617	Backwater	sand	3	2.0	256.0	